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ABSTRACT

This report examines the impact of the Soviet Academy of Sciences on the development of technology in the Soviet Union, finding that the future of Soviet technology depends significantly on the Academy and that severe problems stemming from its nature and its relationship with Soviet industry encumber the Academy's ability to serve Soviet technology. Following an introduction, the report focuses on: (1) the network of Soviet research, development and innovation (RDI) performer institutions, including field limitations, jurisdictional division of research and development (R&D) institutions, and the functional types of R&D institutions; (2) the Academy of Sciences as an R&D performing institution; (3) technological support of the Academy of Sciences; (4) R&D sources of the Academy of Sciences, including fields and levels of R&D activity and relative importance of Academy institutes, and classification of R&D institutes of the Academy of Sciences system; and (5) a brief discussion of the conclusions. Institutes of the USSR Academy of Sciences and Republic Academies and a table indicating the distribution of scientific workers by republic and sector are included in the appendices. (Author/SK)

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The Soviet Academy of Sciences and Technological Development

Simon Kassel
Cathleen Campbell

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PREFACE

This report was prepared in the course of a preliminary phase of a study of Soviet science and technology sponsored by the Defense Advanced Research Projects Agency. The study undertakes a systematic analysis of Soviet R&D resources and their performance.

The report should be of interest to scholars and U.S. government officials involved in U.S.-USSR technology transfer.

SUMMARY

This report examines the impact of the Academy of Sciences on the development of technology in the Soviet Union. It finds that the future of Soviet technology depends significantly on the Academy and that severe problems stemming from its nature and its relationship with Soviet industry encumber the Academy's ability to serve Soviet technology.

The Academy's importance derives from its unique position of national leadership in planning, coordinating, and performing R&D and from the fact that it is expected to help solve the problems affecting Soviet industrial innovation. The Academy's statutes identify it as a scientific institution dedicated to the independent pursuit of knowledge, i.e., basic research. However, the Academy's effective contribution to technological development requires a substantial departure from the statutory mission of basic research in favor of more-or-less direct involvement with industry, particularly in the successive stages of the research, development, and innovation (RDI) cycle.

A survey of all Academy research institutes indicates an R&D configuration promoting such involvement. Two-thirds of all Academy research institutes form a set that is relevant to the development of technology. More than one-half of this set is oriented toward applied research and development, as distinct from basic research. Among the Academy's major R&D facilities in the RSFSR and Ukraine, two-thirds of the technologically relevant institutes are so oriented.

A particularly strong effort in applied research and development is evident in the specialized fields of physics and chemistry advancing critical industrial and defense technologies. The Siberian Department of the Academy of Sciences, USSR, and the Ukrainian Academy provide examples of extensive involvement in the industrial process. The success of Academy-industry cooperation is limited by a fundamental flaw of the system: The Academy's administrative separation from industrial R&D institutions leads to the need for a complex bureaucratic network to bridge the gap; the bureaucratic superstructure, in turn, impedes innovation. The resulting fragmentation of the RDI cycle indicates continuing problems with the industrial innovation process in the affected technologies.

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I. INTRODUCTION

This report documents the initial phase of a long-term study of the potential for development of Soviet science and technology. The uncertain perception in the United States of the strengths, weaknesses, and capability for future development of Soviet scientific and technological performance and the complexity of evaluating it require such an extensive study program.

The achievements of Soviet S&T appear to be more uneven than those of the West. In some areas, Soviet technology equals, and in isolated cases surpasses, Western achievement levels. In other areas, Soviet technology, while appearing less sophisticated than its Western counterpart, seems to reflect a deliberate Soviet choice for simplicity without compromising utility. Still others, of which computer technology is the best-known example, reveal a development level that falls considerably below Western standards and that cannot be attributed to the choice of a simple-but-adequate approach. Other examples include materials technology, integrated circuits, and high-precision test equipment and generally involve advanced or "high" technologies.

The disparity between the high technologies and the more traditional technological areas can be regarded as one of many contrasting phenomena characterizing Soviet society. A conspicuous disparity exists between the military and civilian sectors of the Soviet economy. A less well explored disparity appears between the scope of the Soviet science establishment and the overall results of Soviet scientific research. To wit, the Soviet higher education system graduates more specialists in engineering sciences than the U.S., and the research institutes of the Academy of Sciences and of industry cover the major research fields impressively (see Appendix A). Nevertheless, in only a few areas can Soviet applied research claim discovery priority or superiority to Western accomplishments. The relative availability of trained manpower and the scarcity of experimental equipment create yet another disparity--that between the theoretical and experimental aspects of Soviet research.

These Soviet departures from the norms and proportions characterizing Western technology, because they are typically Soviet phenomena, should be studied systematically in any predictive assessment of Soviet technological capability. A thorough consideration of Soviet disparities may establish the first line of defense against the hazard of "mirror-imaging," that is, of projecting Western norms and expectations into the prediction of Soviet technological development.

The problems and disparities involved in the Soviet research, development, and innovation (RDI) cycle can be considered from a number of viewpoints. Foreign studies have so far emphasized the economics of Soviet S&T. These studies have pointed, first, to the absence of a developed civilian market to stimulate adequate innovation efforts and, second, to the system of industrial incentives that inhibit innovation in favor of established production goals as the major economic factors affecting the Soviet RDI cycle.

Other equally important aspects of the Soviet RDI cycle concern the management and organization of the cycle and the physical resources available for R&D, that is, the network of research institutes and laboratories. The physical resources of R&D represent the least known and understood aspect of the Soviet RDI cycle. Nevertheless, the number, size, and quality of the Soviet R&D institutions, and specifically their personnel and facilities, and their modes of deployment in the RDI cycle directly affect the outcome of Soviet industrial innovation efforts. The relationship between the configuration of the R&D resources and the strength or weakness of the resulting technological development deserves thorough and systematic analysis.

This long-term study will analyze the organization and performance of Soviet R&D institutions in the RDI cycle. This first report considers one component of the network: the research institutes of the Academy of Sciences system.

The report addresses first the structure of the Soviet RDI cycle based on the network of specialized R&D performers, characterized by varying degrees of administrative independence from one another and from production organizations. Next, it considers the Academy of Sciences as the principal performer of basic Soviet research and as a

participant in the industrial innovation effort. Particular attention is given to the Academy's role in the Soviet RDI cycle, the organizational problems involved in the interaction between the Academy and the industrial institutions, and the industry's technological support of the Academy as an example of such interaction. Finally, the report presents the preliminary results of an analysis of the research institutes of the Academy system as part of the network of RDI performers. Those Academy institutes of potential significance to technological development are considered in terms of general research fields and the RDI stage in which they may be involved. The array of the institutes thus indicates the varying capability of the Academy across the spectrum of science and technology and the RDI cycle.

II. THE NETWORK OF SOVIET RDI PERFORMERS

The Soviet RDI cycle differs organizationally from that of the technologically advanced Western countries. While the Soviet RDI structure is not the same in all technological areas, in many areas its outstanding characteristic is a chain of separate, specialized performer institutions participating in the cycle.

The RDI performer institutions differ from one another in several major respects:

- First, they specialize according to the fields subdividing science and technology.
- Second, they differ in terms of the administrative jurisdictions to which they belong. The major jurisdictions represent several separate organizational systems, independent of one another.
- Finally, they specialize by RDI stages. As a project progresses along the successive stages of the RDI cycle, it is relayed from one to another of the participating performer institutions.

An RDI cycle involving interdisciplinary projects often employs a mix of performer institutions that differ in all three of the above categories. The mix varies to some extent among the different technologies; in some, the RDI cycle tends to approximate the Western model of a single organization in charge of the entire RDI cycle.[1]

The mix of different institutions in the RDI cycle demands stringent interagency cooperation, precision of timing, and exchange of information across jurisdictional boundaries. These problems bring into focus another important variable characterizing the Soviet RDI cycle as

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[1]This tendency may result in varying degrees of integration of the RDI cycle. For example, each of the military industrial ministries, in addition to production, controls its own research institutes and design organizations. Tank, artillery, and small arms design organizations are attached to the production plants. Arthur J. Alexander, *Decision Making in Soviet Weapons Procurement*, The International Institute for Strategic Studies, 1979, p. 23.

a whole: the degree of organizational separation between the distinct institutions participating in the cycle.

The frequent pleas in the Soviet press for tighter linkage between the participating institutions reflect the general awareness of the deleterious effect of administrative separation on R&D success. In fact, the growing practice of interinstitutional associations and special cooperative arrangements among Soviet R&D and production organizations represents an attempt to overcome this separation. The separation varies considerably within the network of Soviet scientific and industrial hierarchies. The separation is at least nominally shorter within an industrial ministry than between that ministry and an independent organization, such as the Academy of Sciences. One can expect the difficulty of interinstitutional cooperation to be in some way proportional to such separation, unless special linkage is established between the organizations involved.

The structure of the Soviet RDI cycle may thus be described not only in terms of the different participating institutions, but also in terms of the degree of their organizational separation. Such a description, however, must remain imprecise, because the designations (such as research institute, design bureau, etc.) of the institutions are not always consistent with their functions, and a complete set of institutions participating in any given RDI cycle is seldom available.

This report analyzes the Academy of Sciences, in terms of the foregoing variables, as part of the network of Soviet R&D performers. A general outline of the network precedes the discussion of the Academy to provide a context for the latter's activities. The outline is based on the three principal characteristics of the network identified above: field, jurisdiction, and function (RDI stage).

A. FIELD LIMITATIONS

Most Soviet R&D institutions specialize according to the field of their activity. For institutions engaged in scientific research, whether basic or applied, the field is one or more scientific disciplines or their subdivision. For institutions engaged in development, prototype construction, etc., the field may be a sector of engineering or a branch

of the national economy. Thus, the network of R&D performers represents a set of specialized fields. Since the central theme of this study is the development of technology, the study must first identify a subset of fields that relate to technological development. The boundary of this subset constitutes the limits of the present report; unless otherwise noted, what follows concerns only the institutions and activities within the specified subset.

For the purpose of this discussion, relevance to technological development is defined as a reasonable probability that an R&D institution can contribute to or participate in any stage of the RDI cycle in what is generally and loosely considered industrial and military technologies.

The designation of relevant fields is arbitrary; obviously, the relevance of some fields to technological development poses a problem. The approach must tolerate some deviations from the principle for the sake of simplicity in handling the available input data. For example, while biology as a whole is not relevant, some specialized topics in biology (such as biologically active substances in chemical synthesis) are. It is simpler, however, to exclude biology altogether than to identify and account for the relatively few research institutes dealing with these topics. The subset of R&D performers relevant to technological development is specified below according to these considerations.

The field of scientific research (early stages of the RDI cycle) is limited to institutes active in the following disciplines:

Mathematics
Physics
Chemistry
Geophysics
Engineering
(all sectors)

Excluded are astronomy, astrophysics, biology, medicine, veterinary science, social sciences, humanities, economics, and law.

The field of institutions performing R&D in various branches of the national economy (generally middle and late stages of the RDI cycle) is limited to the following subjects:[1]

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[1]These designations follow the standard Soviet breakdown by branches of the national economy.

Industry
Transportation and communications
Geology and mineral prospecting

Excluded are housing and industrial plant construction, agriculture and forestry, and commerce.

The discussion of jurisdiction and function of R&D institutions in the following sections of this chapter, and of the Academy of Sciences in the next chapter, is limited to the fields listed above.

B. THE JURISDICTIONAL DIVISION OF R&D INSTITUTIONS

Soviet institutions performing R&D in the subject areas specified above may belong to one of three main jurisdictions:

1. The Academy of Sciences, USSR, and the separate academies of sciences in each republic of the USSR (except the RSFSR, which is represented by the USSR Academy). The USSR Academy also has regional subdivisions, the most important of which is the Siberian Department.[1]
2. The higher educational institutions (VUZ) operating under the Ministry of Higher and Specialized Secondary Education.
3. The ministries in charge of the specified branches of the national economy, called here the industrial ministries.

Other research institutions are subordinated to such organizational units as state committees (for the utilization of atomic energy, for standards, etc.), state planning organizations (Gosplan), and specialized government departments.

There are no accurate and up-to-date statistical data on the distribution of Soviet R&D institutions among these jurisdictions. The following is an approximate breakdown estimated by us from several sources published between 1976 and 1978:[2]

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[1]The Academy system is generally considered also to include five specialized academies dedicated to subjects excluded in the preceding chapter and therefore not discussed here.

[2]National Foreign Assessment Center, *Directory of Soviet Research Organizations*, CR 78-11336, March 1978; *Directory of the USSR Academy*

	No. of R&D Institutions
Academies of sciences	331
Higher educational institutions (VUZ)	175
Ministry system	1300

Only the estimate for the academies of sciences is presented with a high measure of confidence. The total of 331 is the number of research institutes of the Academy of Sciences, USSR, and the republic academies of sciences relevant to technological development which provide a fairly complete and consistent inventory for this jurisdiction.[1]

The available information on VUZ and ministries is less accurate. The estimate for VUZ was derived from lists that are probably incomplete. It was obtained by counting research institutes relevant to technological development, subordinated to the Ministry of Higher and Secondary Specialized Education or attached to VUZ, and excludes universities and VUZ laboratories. The count of 175 represents the lower limit of a range of probable numbers of VUZ research institutes relevant to technological development.

Even less is known about R&D institutions under the industrial ministries. Duzhenkov gives the total of the so-called scientific institutions in the USSR as 5327 in 1974.[2] According to statistics for 1973, R&D institutions in industry, transport and communications, and geology and mineral prospecting amounted to 24.5 percent of the total.[3] This gives a total of about 1300 R&D institutions in the ministry system, and probably excludes the industrial design organizations. Th[illegible],

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of Sciences, Joint Publications Research Service, Arlington, Va., 1976; *Spravochnik dlya postupayushchikh v Vysshiye uchebnyye zavedeniya SSSR* (Handbook for Entrants into Higher Educational Institutions of the USSR), *Vysshaya shkola* Publishing House, Moscow, 1976; V. I. Duzhenkov, *Problemy organizatsii nauki* (Problems of Organization of Science), *Nauka* Publishing House, Moscow, 1978, p. 94.

[1]For a more detailed breakdown of research institutes of the academies of sciences, see Table 3, p. 44.

[2]Duzhenkov, p. 94.

[3]Duzhenkov, p. 120. Duzhenkov cites *Narodnoye khozyaystvo SSSR v 1973 g.* (National Economy of the USSR for 1973), *Statistika* Publishing House, Moscow, 1974, pp. 180, 182, for this figure. The citation is incorrect, however; the figure does not appear in the cited source.

the number of R&D institutions of the Academy of Sciences in the fields relevant to technological development amounts to over 25 percent of those in the ministry system.

In theory, research institutions of the Academy and VUZ systems perform either basic research or work in the early stages of the RDI cycle, and those of the industrial ministries perform in the middle and late stages of RDI cycle, where they may be in contact with production plants under the jurisdiction of the same industrial ministries. R&D institutions of other organizational units can be dedicated to any stage of the RDI cycle.[1] A hypothetical R&D project might thus originate in an R&D institute under the jurisdiction of the Academy of Sciences or of the higher educational institutions and then proceed through an institute of the ministry system on the way to production in a ministry plant.

Soviet R&D practice, however, does not necessarily follow the correlation between administrative jurisdiction and the RDI stage. The R&D institutes of the industrial ministries may, in some cases, be involved in basic research; conversely, institutes of the Academy of Sciences may complete the entire RDI cycle, including pilot and small-batch production. This circumstance is significant and must be taken into account in the assessment of Soviet technological potential. Actual Soviet practice, as distinct from theory of Soviet R&D based on official statutes and planning, decides the outcome of Soviet technology development.

C. THE FUNCTIONAL TYPES OF R&D INSTITUTIONS

Soviet R&D institutions vary widely and bear a corresponding variety of type designations. The latter usually consist of a general organizational term, such as institute, bureau, laboratory, or plant, and a qualifier, such as scientific research, design, project, test, technological, or experimental. In theory, each designation represents a distinct function related to a specific stage or stages of the RDI cycle. In practice,

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[1] Soviet literature frequently calls R&D institutes of the industrial ministries "branch" institutes to indicate specialization in the industrial branch or sector. Robert Campbell applies this term also to some major institutes under other than ministry jurisdiction, for example, institutes of state committees (*Soviet Energy R&D: Goals, Planning, and Organizations*, The Rand Corporation, R-2253-DOE, May 1978, p. 59).

however, the functions of the different types of R&D institutions overlap, causing considerable ambiguity. This report makes no attempt to provide an exhaustive inventory of the functional types; excellent materials on this subject are available in the literature.[1] The following describes the main types of R&D institutions under the jurisdiction of or cooperating with the Academy of Sciences.

1. Research Institutes

Research institutes or NIIs (nauchno-issledovatel'skiye instituty) form the bulk of the research organizations of the Academy system and are the most prestigious R&D performers of all Soviet R&D organizations. NIIs are also the principal research organizations of the VUZ and the industrial ministry systems. While NIIs are mainly dedicated to the early and middle RDI stages, their activity may span the entire RDI cycle.

2. Research Laboratories

Research laboratories may exist independently within the VUZ and industrial ministry systems, or may be part of industrial production plants. Within the Academy system, research laboratories are part of NIIs.

3. Design Bureaus

The design bureau or KB (konstruktorskoye byuro), found mainly in the industrial ministry system, engages in the middle and late stages of RDI, specializing in product design. In such industrial sectors as aviation, the KB may be as large as a major institute and span the entire RDI cycle. The Academy and VUZ systems also have a limited number of KBs.

4. Technological Institutes

Nolting[2] uses this term to designate institutions that engage primarily in "process designing, or designing of machinery and installations,

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[1] See, for example, Louvan E. Nolting, *The Financing of Research, Development, and Innovation in the USSR, by Type of Performer*, U.S. Department of Commerce, FER-No. 9, April 1976, p. 16.

[2] Ibid., p. 8.

and development of processes for the manufacture of new products or the modernization of production, though they may also be involved in product designing." This category includes such Soviet designations as project-technological (proyektno-tekhnologicheskiye) organizations, institutes, or bureaus; design-technological (konstruktorsko-tekhnologicheskiye) bureaus; and project-design and technological (proyektno-konstruktorskiye i tekhnologicheskiye) bureaus.

5. Experimental Production Plants and Pilot Plants

These organizations engage mainly in constructing and testing industrial prototypes, industrial innovation processes, and sometimes small-batch production. A plant may operate independently within the industrial ministry system or as a component of an NII, KB, or production plant. In some cases, pilot plants are associated with Academy NIIs.

An increasingly important feature of the above R&D institutions is their participation in industrial associations under varying degrees of integrated management. The most notable are the scientific-production associations, or NPO (nauchno-proizvodstvennyye ob"yedineniya), which combine an industrial NII or other type of R&D institution with a production plant and sometimes a pilot plant.[1]

Soviet analysts criticize the weakness of the organizational and economic links between ministry NIIs and the R&D components of industrial plants. Workers in research laboratories and KBs subordinated directly to plants, they say, understand production needs and possibilities better than do NII personnel.[2] Still weaker are the links between the NIIs of the Academy of Sciences and ministry NIIs, KBs, and production plants. As illustrated in Fig. 1, the strength of the linkage between R&D and production decreases with increasing number of

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[1]The NPOs and other associations of this type are not involved with the Academy to any significant extent and therefore will not be discussed in this report. Their role in the RDI cycle will be covered in subsequent reports of this series.

[2]K. I. Taksir, *Nauchno-proizvodstvennyye ob"yedineniya* (Scientific Production Associations), *Nauka* Publishing House, Moscow, 1977, p. 8.

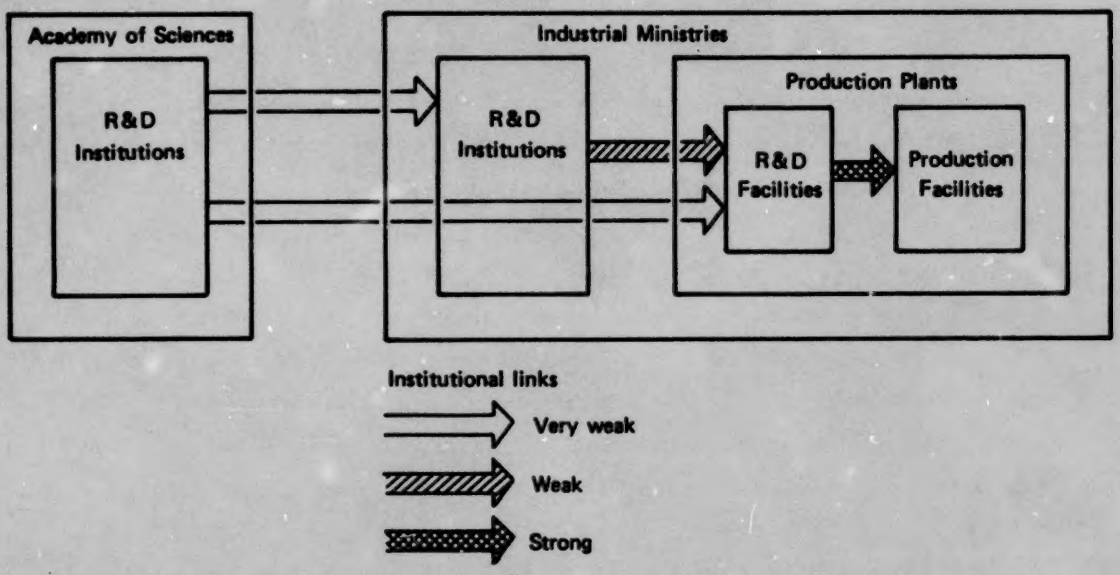

Fig. 1--Organizational barriers between the Academy of Sciences and industry

organizational barriers the links must cross. Since the Academy of Sciences is outside the ministry system, its links to production are the weakest of all. Taksir complains that

> Institutes of the Academy of Sciences are slow to introduce the results of their research into production, basically because of their inadequate linkage to production, industrial NIIs, and KBs. Experience shows that the effectiveness of science increases immeasurably wherever such linkage is established and continuously reinforced.[1]

The Academy of Sciences, despite its primary dedication to basic research, is clearly expected also to maintain links to production. The next chapter explores this task of the Academy in greater detail.

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[1] Ibid., p. 9.

III. THE ACADEMY OF SCIENCES AS RDI PERFORMER

The Academy of Sciences is the most important scientific institution of the USSR. Along with the State Committee for Science and Technology, the Academy serves as one of the national planners, initiators, and coordinators of key scientific and technological research. Unlike the State Committee, however, the Academy is also a leading performer of this research. This combination of management and performance, unique among Soviet S&T institutions, is one reason for its extraordinary prestige and influence.

Another reason is that the Academy has concentrated the foremost scientific talent of the country. As a result, more of the best scientists are drawn to the Academy at the expense of the other Soviet R&D institutions, and the Academy's higher pay scales and better fringe benefits for scientific personnel reinforce its power. Consequently, as both employer and R&D institution, the Academy of Sciences enjoys a formidable advantage over industrial R&D organizations.

The statutes of the Academy of Sciences define its mission as primarily basic research, the type of research generally associated in the West with that performed by the universities. On the face of it, concentration on basic research would make the Academy's work of limited significance to industry and the national economy. But, as we show later, Soviet academicians and government leaders believe that science, and basic research in particular, drive technological development and cause technological breakthroughs. They look to the Academy of Sciences for new solutions to technological problems, the development of advanced technologies, and most important, participation in the continuing effort to overcome the impediments to industrial innovation. The Academy is involved in these activities and has moved considerably beyond basic research, in many cases to the middle and late stages of the RDI cycle.

The ambiguity in the Soviet perception of the Academy's mission may lead to conflicts. The benefits to the academicians stemming from the Academy's practice of basic research, such as its relative freedom to pursue science for its own sake, must be weighed against the benefits

and influence to be gained from the Academy's involvement in the national economy.[1]

The Academy today appears intent on retaining and even reinforcing its statutory emphasis on basic research. A 1977 emendation of the statute of the Academy of Sciences, USSR, introduced the word *basic* to qualify its research mission and eliminated references to specific industrial activities.[2]

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[1]This conflict is not new to the Academy. In the early sixties, many Academy institutes were transferred to industrial jurisdiction so that the Academy could pursue more basic research. The remaining institutes and those established later, however, continued to pursue applied research and development as part of their activity, and the conflict continued.

[2]*Ustavy Akademii nauk SSSR* (Statutes of the Academy of Sciences, USSR), G. K. Skryabin (ed.), *Nauka* Publishing House, Moscow, 1975, p. 165; VAN SSSR, No. 6, 1977, p. 69. Par. 2 of the Statute, in force up to 1977, began as follows:

"The Academy of Sciences, USSR, pursues the following aims:

[1] Development of research in leading areas of the natural and social sciences;

[2] Implementation of promising research directly related to the development of production, with priority to areas [capable of] determining engineering progress, such as nationwide electrification, complex mechanization and automation of production, dissemination of chemical technology throughout the major sectors of national economy, new materials, radioelectronics, utilization of new energy sources, [and] development of new methods of energy conversion. . . ."

In 1977, the first sentence was amended to read: "Development of *basic* research in leading areas of the natural, *engineering*, and social sciences" [emphasis added to indicate new words]. The second sentence was deleted and replaced by: "Identification of new-in-principle paths of engineering progress, creation of a scientific basis for their realization, and development of recommendations for their application to the national economy; implementation of promising research of the important problems of scientific, engineering, and social progress, whose solution [will] determine the successful development of the economy, culture, and science itself; research of general problems of scientific engineering progress and their relation to the environment and well-being of man."

The addition of *basic* indicates the intent to stress the basic nature of the Academy's research. But the simultaneous insertion of *engineering areas* points up the conflict: It is difficult to define basic research in engineering. The substitution of the second sentence removes the Academy from the immediate industrial environment suggested by *electrification, chemical technology, radioelectronics*, etc., and places it on a more elevated plane where it is responsible for scientific, engineering, and social progress.

Members of the Academy emphasize the scientific aspect of the Academy's activity:

> The development of fundamental themes of science is the main task of the Academy. The results of basic research are the fundamental criteria of its performance. . . .[1] The focus on cooperation between the Academy and industrial science should not detract from the importance of basic research. . . .[2] We see our main mission as the development of basic research.[3]

Yet, Academy Vice President Fedoseyev also wrote:

> However, the scientific teams performing basic research should also keep an eye on the possibilities of application . . . [and] are *obligated* to consider also applied research and to reveal new opportunities for technological and social progress.[4]

Paton's Ukrainian Academy and the Siberian Department of the Academy of Sciences, USSR, have for a number of years led the efforts to cooperate with industry. Soviet leaders welcomed their industrial initiative. Brezhnev stated:

> We consider it essential, while developing basic research, to effect its organic union with applied research, and to accelerate innovation. . . . The Central Committee of the Communist Party approves and supports the Ukrainian and Siberian efforts which succeeded in converting science into a directly productive force.[5]

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[1] *Vestnik Akademii nauk SSSR* (Proceedings of the Academy of Sciences, USSR; hereinafter called *VAN SSSR*), P. N. Fedoseyev, Vice President, Academy of Sciences, USSR, No. 9, 1976, p. 12.

[2] Academician A. V. Sidorenko, ibid., p. 30.

[3] B. Ye. Paton, President, Ukrainian Academy of Sciences, ibid., p. 33.

[4] *VAN SSSR*, No. 9, 1976, p. 12 (emphasis added).

[5] *VAN SSSR*, No. 5, 1977, p. 6.

Either as a result of government pressure or its own convictions, the Academy has been promoting the concept that it is in the best position to provide technological breakthroughs. According to the academicians, one must look to science, rather than to industry, for solutions to the basic Soviet problem of industrial innovation. The solutions will be based on new scientific principles that will provide shortcuts through the old intractable technological problems.

This concept was most clearly articulated in the Resolutions of the 1976 General Meeting of the Academy of Sciences, USSR:

> The enhanced role of basic science, which is the *source of* new *engineering solutions* and an important cause of acceleration of scientific and engineering progress, further increases the role of the Academy of Sciences, USSR, as the center of theoretical research and coordinator of all scientific research in the country.[1]

Such statements indicate a conviction that the USSR's technological lag cannot be overcome by the massive application of conventional effort, but rather requires new and ingenious technological solutions. Much of this ingenuity is expected to come from the Academy of Sciences.

This requirement places the Academy in a position of profound conflict. As a main mission of the Academy, basic research, the earliest stage of the RDI cycle, excludes direct technological innovation activity and the development of industrial technologies. Technological innovation is a late stage of the cycle and is generally under the

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[1] *VAN SSSR*, No. 9, 1976, p. 80 (emphasis added). These ideas appear to have been carefully orchestrated among the leadership of the Academy; some members made even more positive statements. Fedoseyev, for example, wrote: "The general mission of the Academy of Sciences is the further study of the laws of nature and society, and the forging of basically new approaches and possibilities for the transformation of the productive forces and the creation of future technologies." (Ibid., p. 15.) Paton said: "The special feature of the current stage of development of science is the enhanced role of basic research, opening up basically new paths and possibilities for the development of the national productive forces and the creation of future technology. This research is concentrated mainly in the Academy of Sciences, USSR, and in the republic academies. (Ibid., p. 33.)

jurisdiction of the industrial ministry system, which is organizationally remote from the Academy system. To participate in the technological innovation effort, the Academy must attempt to span the RDI cycle by some measure of direct involvement in its middle and late stages and, at the same time, overcome the organizational separation from the production facilities. Both tasks imply essentially a violation of the Academy's basic charter. The Academy has attempted both with limited success.

The Academy leadership, conscious of the inadequate relationship between science and industry, repeatedly exhorts members to strengthen the ties between science and industry, which "is the direct responsibility of scientists."[1] They feel that closer ties will accelerate the *vnedreniye*[2] process, which "often proceeds slowly and incompletely."[3]

Some Academy institutes acquire special facilities to carry R&D to the late stages of the cycle. The Institute of Organic Chemistry, for example, develops chemicals and drugs to be mass-produced by industry, and the Institute of Crystallography delivers prototypes of equipment and crystal synthesis technology directly to industrial production plants.[4] The Institute of Organic Chemistry was one of the Academy's first institutes to build its own development and test facilities for prototype production. The Institute of Crystallography has a number of its own special design bureaus to make prototypes.

The requirements of the RDI cycle justify this practice. According to S. R. Mikulinskiy, Director of the Institute of the History of Science and Technology,

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[1] *VAN SSSR*, No. 7, 1977, p. 89.

[2] The Russian word *vnedreniye* means the introduction of the results of R&D into production; it is often translated *innovation*.

[3] *VAN SSSR*, No. 6, 1979, p. 15.

[4] G. I. Levi, Zelinskiy Institute of Organic Chemistry, Academy of Sciences, USSR, *VAN SSSR*, No. 2, 1977, p. 7. B. K. Vaynshteyn, "Proceedings of the General Meeting, Academy of Sciences, USSR," *VAN SSSR*, No. 9, 1976, p. 65.

> The key problem is the coupling of science to production, or the rapid introduction of scientific achievements into production. While this is primarily the business of industrial institutes, prototype design bureaus, and the production plants themselves with their laboratories, it also entails the solution of theoretical problems. Consequently, it involves the participation of Academy institutes.[1]

Solving theoretical problems, however, is only part of what the Academy is called upon to do to help couple science to production; it is expected also to participate directly in the late stages of RDI. To do this, it must span the organizational separation from industrial innovation. The need for such an effort has been articulated at many levels of Soviet science and government. At the top of the Soviet hierarchy, Brezhnev, as noted above, invoked in general the need for an organic union between the basic and applied research and innovation. At the Academy leadership level, Fedoseyev noted that

> . . . scientific achievements are realized by the establishment of direct links between Academy institutions and industrial research institutes, enterprises, and associations.[2]

At the level of the individual research institute, the experience of the Institute of Organic Chemistry indicated that

> . . . innovation was most successful when there was a direct contact with the plant which was strongly interested in the new development.[3]

It can be seen from the above that as the requirements descend the ladder of authority, they include not only more specific ideas, but also specific provisions for less separation from production. Fedoseyev

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[1] S. R. Mikulinskiy, *Research--Development--Innovation*, Institute of the History of Science and Technology, Moscow, 1970.

[2] *VAN SSSR*, No. 9, 1976, p. 20.

[3] *VAN SSSR*, No. 2, 1977, p. 8.

found it necessary to include industrial institutes in the bridges to industry, while practical experience at the institute level dictated direct links to production. Such links require that the Academy institutes possess adequate experimental and pilot production facilities.[1]

Although some institutes acquire such facilities, the Academy also considers other forms of linkage to industry, involving special interagency relations.[2]

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[1]The problem was spelled out by Yu. K. Pozhela, Vice President, Lithuanian Academy of Sciences: "If one insists that research results obtained in an Academy institute reach the plant 'in metal' rather than 'on paper,' in the form of finished prototypes, instruments, etc., the institute must have a production base. However, insofar as the structure of Academy institutes does not include such a base, it is being established in the form of individual contract-funded enterprises regulated according to the industrial model, but most often subordinated to the [Academy] institute. At this time, such enterprises operate at many Academy institutes with successful results, particularly in the Ukrainian Academy of Sciences and in the Siberian Department of the Academy of Sciences, USSR. (*VAN SSSR*, No. 9, 1977, p. 25.)

The establishment of such enterprises is not confined to Ukrainian and Siberian institutes. During its development, the Solid-State Physics Institute, Academy of Sciences, USSR, assigned high priority to industrial innovation. This led to the installation of such facilities as a "technology wing" to produce test batches of finished materials. Representatives of the Academy noted that "achievements of the institute were made possible by the combination of basic and applied research deliberately pursued since the foundation of the institute. Good leadership by the research laboratories and strong technological capability assured the institute's success." The technological part of the institute pursues two aims: it directly supports the research work of the institute and makes industrial innovation possible. According to A. M. Prokhorov, secretary, General Physics and Astronomy Division of the Academy, solid-state physics can develop today only with the support of an adequate technological base, as demonstrated by the institute. A. P. Aleksandrov, president, Academy of Sciences, USSR, stated that the institute's structure, basic research, and industrial linkage render the Institute of Solid-State Physics a model modern R&D facility to be supported as much as possible. ("On the Activities of the Institute of Solid-State Physics," *VAN SSSR*, No. 2, 1977, p. 3.)

[2]The Physics Institute of the Siberian Department, for example, developed and built small batches of digital spectrographs, quantum filters, bathyphotometers, and traveling-wave solenoids, which it sold to industry for profit. Although mass production could have greatly increased the profit, the institute found it uneconomical to establish its own production base and suggested instead an organization of interinstitute pilot plants. (*Pravda*, May 14, 1978, p. 3, cols. 2-6.)

There is no standardized framework for Academy-industry cooperation. The theoretical model considered most effective is based on the so-called three-link concept: Academy of Sciences--industrial research institute--industrial plant. The three organizational links span the entire RDI cycle, including basic research, innovation, and diffusion.[1] However, a key Soviet R&D administrator states that this model is not widely used because it cannot be achieved by any standard administrative mechanism, but requires special government measures for implementation.[2]

To tighten the links between the Academy and the ministries, it was proposed that the leading industrial institutes should be better represented at the Academy, for example, by subordinating some leading institutes to both the Academy and the ministry.[3] Proposals of this kind indicate Soviet awareness of the problems created by the administrative separation of science and industry.

Modifications of the three-link concept are realized in practice at the initiative of local research and industrial leaders. These individuals are generally members of the Academy of Sciences operating either within the Academy system itself or in industry, as heads of industrial research institutes. The Academy is able to influence industry through its members working in industrial institutions.

In general, the Academy of Sciences and industry interact on three levels. On the Academy side, the top level of interaction involves the leadership, represented by the presidium of the Academy. The middle level involves large organizational units of the Academy system incorporating a number of R&D institutes. The bottom level involves individual R&D institutes of the Academy system. The Academy-industry interaction typical of each level is illustrated below.

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[1]Academy President Aleksandrov used the development of the Soviet atomic bomb as an example of the operation of a three-link model: The development, begun in 1943, involved many institutes of the Academy of Sciences, prominent industrial organizers, engineers, and specially established industrial scientific and production organizations. (*VAN SSSR*, No. 4, 1976, p. 5.)

[2]N. S. Lidorenko, "Accelerating the Utilization of Basic Research Results," *VAN SSSR*, No. 9, 1976, p. 96.

[3]Ibid., p. 102.

At the leadership level, the Academy of Sciences, USSR, participates in the planning, coordination, and implementation of major national programs in advanced areas of R&D. The overall responsibility for these functions rests with the Academy presidium, which manages them through the Academy's major divisions and through scientific councils formed for that purpose.

The national program for electrical energy R&D is an example of such an effort. The energy program is administered by the Division of Applied Physical Problems of Power Engineering, Academy of Sciences, USSR. In 1968, the Scientific Council on Theoretical and Electrophysical Problems of Electric Power was established as the executive arm of the division in the area of electric power R&D.

The council maintains "working-level contact" with the State Committee for Science and Technology; this probably means that the two groups coordinate priorities for specific major R&D objectives. Such coordination is required in view of the council's official primary mandate--to focus on "the most urgent and promising" R&D work in the electric power area.

The council also has direct relations with over 40 research organizations whose parent institutions include the Academy of Sciences, VUZ, and industrial ministries. The council's degree of control over the R&D work of these organizations ranges from planning and coordinating the entire R&D activity, through assigning individual projects, to maintaining permanent cooperation with the organization.[1] In this mode of Academy-industry interaction, the Academy in effect runs a large-scale R&D program.

At the large organization level, two outstanding units of the Academy of Sciences system, the Ukrainian Academy of Sciences and the Siberian Department, Academy of Sciences, USSR, currently manage extensive Academy-industry interaction efforts.

The Ukrainian Academy of Sciences has developed a particularly strong and cooperative relationship with industry, thanks largely to

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[1] See also: Simon Kassel, *Pulsed Power Research and Development in the USSR*, The Rand Corporation, R-2212-ARPA, May 1978, pp. 3ff.

the initiative of B. Ye. Paton, president, Ukrainian Academy of Sciences, and director, Paton Institute of Electric Welding. Paton stated that his purpose was to "overcome the external bureaucratic barriers" constraining many Academy institutes.[1]

Paton complained also of the Academy's inadequate access to industrial test facilities and insufficient industrial support of its R&D effort, both of which he considers essential for getting R&D results into production. In many cases, according to Paton, ar industry appears unwilling to participate in the implementation of scientific advances, and production plants "do not seem as responsible for implementing new technology as they are for fulfilling production plans."[2] To compensate for these deficiencies, the Ukrainian Academy institutes, under Paton's leadership, have acquired extensive experimental and pilot production facilities and have been developing new technological processes, machines, instruments, and accessory equipment. Paton noted that the number of experimental production establishments in the Ukrainian Academy increased from 16 in 1967 to 54 in 1977. He sees this growth as "one of the most important factors in increasing the effectiveness of the Academy's work."[3]

The industrial activity of the Ukrainian Academy of Sciences is important and extensive. However, effective interaction between the Ukrainian Academy of Sciences and Ukrainian and all-union industry has required a number of special organizational arrangements. One can identify the following distinct forms of such arrangements:

1. A broad industrial innovation[4] program conducted by the Ukrainian Academy of Sciences and authorized at the top USSR and Ukrainian government levels.

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[1]B. Ye. Paton, "Speech at the General Meeting of the Academy of Sciences, USSR," *VAN SSSR*, No. 9, 1976, p. 33ff.

[2]B. Ye. Paton, "Progressive Forms of Science and Industry Alliance," *Trud*, 27 October 1976, p. 2.

[3]B. Ye. Paton, "The Effectiveness of Scientific Research and the Acceleration of the Vnedreniye Process," *VAN SSSR*, No. 3, 1977.

[4]The expression for industrial innovation is literally "introduction into practice of important results of scientific research." We interpret "practice" to mean industrial activity.

The Soviets hope that such authorization will enable them to overcome the organizational separation and to speed the research, development, and innovation process. Cooperation between scientific research institutes and industry, notable for the large scale of the work and the large number of participants involved, is sought when the work transcends the ability and competence of individual ministries and agencies. A number of proposals of the Ukrainian Academy to accelerate technical progress and to increase labor productivity were authorized by the USSR Council of Ministers, the State Committee for Science and Technology, the Ukrainian Council of Ministers, and other executive agencies.[1] The proposals were incorporated in the Ninth Five-Year Plan.

2. Joint R&D programs conducted by the Academy and individual ministries on both the republic and all-union levels.

Programs have been established with Ukrainian republic ministries in areas considered to have special importance to the Ukrainian economy. Examples include ferrous metallurgy, geology, and power engineering and electrification. On the all-union ministry level, the programs involve the development of experimental production and test facilities. For example, the cooperative program with the Ministry of the Chemical Industry includes 12 Ukrainian Academy institutes, 35 branch scientific-research institutes and design organizations, and 36 industrial associations and enterprises.[2] In 1977 the Ukrainian Academy participated in 16 joint programs with individual ministries, 7 at the all-union level and 9 at the republic level.[3]

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[1]V. Ye. Tonkal', V. M. Pelykh, and B. S. Stegnyy, *Akademiya nauk Ukrainskoy SSR*, *Naukova Dumka* Publishers, Kiev, 1979, pp. 73-74. Industries involved in this effort include welding, clothing manufacture, electric heating, power metallurgy, cermet materials, and cast-iron production.

[2]G. M. Dobrov, Ye. M. Zadorozhnyy, and T. I. Shchedrina, *Upravleniye effektivnost'yu nauchnoy deyatel'nosti*, *Naukova Dumka* Publishers, Kiev, 1978, p. 108.

[3]B. Ye. Tonkal' et al., p. 71.

3. Scientific-technical complexes consisting of an Academy institute, design bureau, pilot plant, and production plant.

The main mission of the scientific-technical complexes is the production support of research, support that significantly accelerates the research itself and, at the same time, promotes the rapid and reliable completion of the R&D projects to the point where results can be introduced into the national economy. These complexes, established around physical, engineering, materials study, chemical, and even biological institutes, employ 22,000 workers, approximately one-third of the work force of the Ukrainian Academy.[1] Paton stresses that the principal advantage of the scientific-technical complex is that it spans the entire RDI cycle, from idea to innovation, thereby enhancing the effectiveness of Soviet research. The disadvantages, according to Paton, are that the complex is not a legal entity and that each participating organization retains its administrative independence. Management is inadequately centralized, and there is no straight-through planning and no common support and supply base.[2]

Paton believes that the main problem of the Soviet RDI cycle is its fragmentation. To be effective, the entire RDI cycle must be

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[1] M. S. Pivovarov, director, Poltava Artificial Diamonds and Diamond Tool Plant, Ministry of Machine Tool and Tool Industry, described the formation of one such scientific-technical complex. The Poltava plant, the leading producer of synthetic diamonds, wanted to establish ties with research institutes engaged in related R&D. Since the Ministry of Machine Tool and Tool Industry had no such institutes, the Poltava plant turned to the leading Academy institutes in the field of superhard materials: the Institute of Physics of High Pressures, Academy of Sciences, USSR, and the Institute of Superhard Materials, Academy of Sciences, Ukrainian SSR. Because no organizational mechanism exists for creating an NPO that includes an Academy research institute, they decided to form a scientific-technical complex. This was set up as a voluntary organization including the Poltava and other plants and several research institutes. Organizational questions within the complex are resolved by a collegium of the directors of the member organizations. Scientific problems are dealt with by a scientific-technical council of specialists. *VAN SSSR*, No. 3, 1977, p. 51.

[2] *VAN SSSR*, No. 9, 1976, pp. 33ff.

subordinated to a single management and implemented preferably by a single R&D performer organization. As an approach to such a structure, Paton proposes a new organizational concept--the academic scientific-technical association (ANTO)--to replace the scientific-technical complex. Starting with fundamental research, the ANTO would carry through to the introduction of prototypes into production.[1]

Brezhnev praised Paton's initiative. *Pravda* described the ANTO as a closed RDI cycle, consolidating institutes, large design bureaus, and experimental and pilot production plants.[2] No mention was made, however, of whether official approval had been given to the large-scale organization of such associations.

4. Direct agreements between the Ukrainian Academy and individual plants.

The first such agreement was signed in 1976 with the Likhachev Automobile Plant in Moscow to develop a waste-free machine-building technology. The Academy currently participates in 20 programs with various enterprises, including the Krivoy-Rog Ore Dressing Combine and the Artemugol' coal production association.[3]

5. Branch laboratories established at either institutes or industrial enterprises.

Branch laboratories are financed by the ministries but fall under the scientific supervision of the Academy. They engage in work which Academy institutes, even those with a developed experimental production base, are not equipped to perform. Many laboratories, such as those attached to the Ukrainian Academy's Donetsk Physico-Technical Institute

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[1] B. Ye. Paton, "Effectiveness of Scientific Research and Acceleration of Innovation," *VAN SSSR*, No. 3, 1977, p. 51.

[2] *Pravda*, January 19, 1979, p. 2, cols. 6-9.

[3] V. Ye. Tonkal' et al., pp. 71-72.

and the Institute of Semiconductors, claim success in industrial innovation. Examples of areas where branch laboratories have been used include physics, cybernetics, electrodynamics, radiophysics and electronics, machine building, and physical mechanics. The Ukrainian Academy has so far established 26 branch laboratories.[1]

The Ukrainian Academy's attempts to introduce new mechanisms for overcoming the organizational separation of RDI performers are highly regarded by Soviet leaders. A resolution passed at the 1976 joint meeting of the State Committee for Science and Technology and the USSR Academy presidium recommended that all ministries and departments follow the Ukrainian Academy's example of successful involvement in the RDI cycle.[2] The Ukrainian Academy is expected to continue to investigate means of improving the science-production ties.

The Siberian Department of the Academy of Sciences, USSR, has a somewhat narrower range of linkage with industry, aimed at unifying basic and applied research, development, and innovation. These forms are as follows:

1. Complex long-term research and innovation programs set up jointly with industrial ministries and authorized bilaterally by the presidium of the Siberian Department and the ministry.

These programs are designed to deal with the major scientific-engineering problems of the given industry. At present, the Siberian Department is conducting bilateral programs with eight ministries.[3]

2. Industrial-type research institutes and special design bureaus with pilot production facilities established to form a linkage between the Siberian Department of the Academy and the industry.

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[1] B. Ye. Paton, "Increasing the Effectiveness of Research," *Trud*, October 27, 1976, p. 2.

[2] V. Ye. Tonkal' et al., p. 63.

[3] N. V. Belov et al., *Nauka--Narodnomy khozyastvu* (Science for the National Economy), *Sovetskaya Rossiya* Publishers, Moscow, 1979, p. 20.

These institutes and bureaus are subordinated to the ministries, but are under the technical supervision of the Academy. Ten USSR ministries and agencies have established such entities.[1] By providing both scientific projects and trained personnel, the Siberian Department enables the institutes and bureaus to begin development and design at an earlier stage of the RDI cycle.[2]

3. Cooperative projects involving a group of Academy institutes and a large industrial enterprise.

This form has only been used once, in the case of the reconstruction of the Sibsel'mash agricultural machinery plant.

A common failure of the above methods of interagency cooperation is the absence of a mechanism for disseminating information on new developments beyond a single ministry or industry. The only effective transmission method is through the industrial branch institute communicating with a number of plants, limited, however, to the same industrial branch. Other industries, even if they are active in a supporting role, are not connected to the dissemination network.

The CPSU Central Committee, emphasizing the importance of the Siberian Department's work, indicated its support of the USSR Academy's proposal to expand the department's experimental production base.[3] The Academy considers such a base essential. The absence or insufficient development of such a base, by impeding the introduction of Academy research results into production, hinders the research-development-innovation process.

The repeated emphasis on establishing experimental production facilities in the Academy implies a lack of confidence in existing organizational arrangements. The creation of joint laboratories under the

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[1] Some authors call these entities MKOs (mezhotraslevyye konstruktorskiye otdely) or interbranch design departments.

[2] G. I. Marchuk, "Siberian Science," *VAN SSSR*, No. 5, 1977, p. 73.

[3] "In the CPSU, Central Committee," *Pravda*, February 11, 1977, p. 1, cols. 1-3.

financial administration of the ministries but under the scientific leadership of the Academy failed to correct the problem. According to the Academy's leaders, the solution lies in developing the Academy's own production base. In this respect, the Ukrainian Academy and the Siberian Department are presented as models for other republic academies to follow.

Both the Ukrainian and Siberian experiences are distinguished by close academic cooperation with the industry. Both also represent attempts to overcome the distance between academic and industrial organizations. There is a difference, however, in the approach taken by the Ukrainian and the Siberian leaderships.

The conventional measures for industrial cooperation adopted by the Siberian Department do not appear to change the basic organizational structure of the Soviet RDI cycle with all its problems. G. I. Marchuk, president of the Siberian Department, writes that the existing organizational system provides many opportunities for Academy-industry cooperation but that scientists and production personnel do not pursue these opportunities actively enough.[1] The Ukrainian approach, on the other hand, indicates an awareness of the fragmentation problem and an attempt to modify the RDI structure itself. This approach, representing the initiative of B. Ye. Paton, exemplifies the impact an individual can have on the Soviet bureaucratic system.

At the individual institute level, institutes of the Academy of Sciences making cooperative arrangements with industrial organizations provide an example of the Academy institute--industrial institute--industrial plant three-link model.

The Chromatography Laboratory, Arbuzov Institute of Organic and Physical Chemistry, Academy of Sciences, USSR, for example, has a cooperative arrangement with the All-Union Research Institute for Hydrocarbon Materials, Ministry of Petroleum-Processing and Petrochemical Industry, USSR, and with industrial plants actively introducing new methods of chemical analysis.[2] Research on the application of liquid

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[1] N. V. Belov et al., p. 27.

[2] M. S. Vigdergauz and R. V. Vigalok, "Chromatography: Research and Innovation," *VAN SSSR*, No. 10, 1977, pp. 73ff.

crystals to gas chromatography was performed jointly by the Academy and industrial institutes, and the resulting material was handed over to the Khar'kov Chemical Reagent Plant for production.

In another case, the Arbuzov institute did not need the help of an industrial institute; it was able to complete the process of innovation with the cooperation of the user plant, part of the Nizhnekamskiy Petrochemical Combine. The Academy considered the cooperation between Academy institute and industrial plant a successful conversion from a three-link to a two-link operation.

A different type of individual institutional linkage, based on the "scientific leadership" principle, is exemplified by the All-Union Research Institute of Electric Current Sources, which is under the jurisdiction of the Ministry of Instrument-Building, Automation Equipment, and Control Systems and, at the same time, under the scientific leadership of the Academy of Sciences, USSR.[1] Under this arrangement, the Academy controls the content and performance of the institute's research activity. In practice, the institute is also closely tied to the Academy and its institutes by N. S. Lidorenko's dual role as director of the institute and corresponding member of the Academy. The scope of the Academy's involvement in industry is indicated by the fact that the Institute of Electric Current Sources is a major research center for direct energy conversion and responsible for its national development.[2]

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[1] N. S. Lidorenko, "Accelerating Innovation of Basic Research Results," *VAN SSSR*, No. 9, 1976, pp. 96ff.

[2] According to Lidorenko, the institute employs over 300 Ph.D.-equivalent scientists, ibid.

IV. TECHNOLOGICAL SUPPORT OF THE ACADEMY OF SCIENCES

The Academy's relationship with an industry often involves the Academy's supply of research instrumentation and equipment. The importance of this issue to the Soviets is indicated by the frequency with which they address it and by its relevance to problems of Academy-industry relations.

The Academy's difficulties in acquiring adequate technological support are often similar to those encountered in cooperating with an industry on innovation projects. In both cases, the Academy must weigh the alternatives of establishing its own development and pilot production facilities and relying on the industry's uncertain support.

The problem of obtaining adequate technological support is not limited to Academy institutes; it extends to all Soviet R&D organizations. One explanation for this situation is that in some areas, such as computers and automation, both of which play key roles in the technological support of R&D, Soviet technology is below the level necessary to meet current R&D demands. Similarly, the development of new instruments and measuring devices continues to fall short of the requirements. A separate Ministry for Production of Instruments, Means of Automation, and Control Systems was created to improve the supply system,[1] but despite some recent gains, supply has failed to improve significantly.

Several dozen other ministries and departments also develop and produce scientific instruments.[2] This scattering of production, coupled with the absence of a single administrative body coordinating a unified policy, results in a severely inefficient system for equipment development, production, and distribution.

The problem is compounded for Academy research institutes. They must deal not only with the scattering of development and production

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[1]John Turkevich, "Soviet Science Policy Formation," in John R. Thomas and Ursula M. Kruze-Vaucienne (eds.), *Soviet Science and Technology, Domestic and Foreign Perspectives*, National Science Foundation, 1977, pp. 31-32.

[2]*VAN SSSR*, No. 8, 1977, p. 43.

responsibilities among many ministries, but must also overcome the jurisdictional boundaries separating them from the ministry system. Furthermore, the plants producing new equipment fill the orders of their own ministry institutes before those of the Academy. Paton argues that industrial suppliers generally assign a low priority to the Academy's requests and that orders from many other organizations, including those from the local industry, are completed ahead of orders from the Academy.[1]

This fragmented production system causes long delays in the completion of new equipment. One academician writes that "the existing system threatens research, since orders [for new equipment] are filled a year or two after they are placed."[2] Another source notes that five or six years may elapse between the initial development of a new instrument and its delivery to and installation in a scientific establishment.[3] One possible consequence of such delays is that new instruments have become obsolete by the time they are available for use.

In addition to problems of supply, the Soviets face a persistent problem of quality control. Very few instruments receive a "high-quality" rating. A sample check of control and measuring instruments in several Moscow enterprises showed that, in general, their quality was below par and that in some cases as many as half the instruments examined were unfit for use.[4]

Even after new equipment reaches a research institute, it is not always fully utilized. The Academy leadership frequently emphasizes the need to correct problems of equipment misuse. A group of auditors found that in the Novosibirsk region instruments and equipment worth 11.3 million rubles stand idle and that some instruments have not been used for up to ten years.[5] Under the current system, institutes

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[1] *VAN SSSR*, No. 6, 1977, pp. 64-65.

[2] *VAN SSSR*, No. 1, 1978, p. 41.

[3] *VAN SSSR*, No. 8, 1977, p. 43.

[4] Raymond Hutchings, *Soviet Science, Technology, and Design, Interaction and Convergence*, Oxford University Press, London, 1976, p. 104.

[5] *Pravda*, May 15, 1978, p. 3, cols. 1-5.

generally acquire new equipment for a specific project. After the project is completed, the equipment often stands idle, even when another institute could use it.

The fact that the Academy leadership repeatedly urges the establishment of its own production base for instruments and equipment signifies a lack of faith in finding a solution under the current arrangement.[1] It also indicates the importance the Academy leadership attaches to the creation of its own production base. The Academy finds that without such a production capability, its institutes will not receive the technological support needed to carry out their R&D activities.

Although the Academy's overall expenditures on new equipment and instruments still fall short of the desired level, they have been increasing steadily.[2] In keeping with the intent to develop its own instrument and equipment production capability, the Academy has also been continuing to channel funds into instrument production. The Ukrainian Academy of Sciences, the Siberian Department of the USSR Academy of Sciences, and the Belorussian Academy of Sciences are cited for the progress they have achieved in establishing an instrument-production base.

The Academy uses two organizational mechanisms for establishing such a base. One, the branch laboratory (see above, p. 25) links an Academy research institute with a production plant. For example, an opto-electronics laboratory was created in conjunction with the Institute of Semiconductors, Ukrainian Academy of Sciences, and the Tochelektropribor plant. Together they developed and produced (for the first time in the USSR) solid-state digital display instruments.

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[1]References to the Academy's need of a production base are numerous. The CPSU Central Committee noted that "the insufficient development of a production base for instruments results in the Academy's inability to produce the latest instruments and means of automation" (*Pravda*, February 11, 1977, p. 1, cols. 1-3). This issue is raised each year at the annual meeting of the USSR Academy of Sciences.

[2]The amount spent on new equipment in 1975 exceeded the 1965 level by 838 percent (*VAN SSSR*, No. 8, 1977, p. 42).

The second organizational arrangement involving direct Academy participation in instrument production, the NTO (nauchno-tekhnicheskoye ob"yedeneniye), or scientific-technical association, combines Academy research institutes with industrial design and production facilities. The NTOs produce instruments for USSR and republic Academy institutes and for export abroad. Production in 1977, which exceeded the 1976 level by 22 percent, included 125 types of equipment, 26 of which were sold abroad.[1]

A production base controlled by the Academy has the important advantage of ensuring the development and production of the type of equipment that the Academy needs. The current supply system favors ministry institutes in that both the plants producing the equipment and the research institutes using it belong to the same system and can interact unimpeded by jurisdictional separation. Conversely, the jurisdictional separation of Academy research institutes from these production plants discourages the latter's responsiveness to the Academy's needs.

Equipment produced by the Academy for the Academy can be expected to be of a higher quality than that which the Academy receives from industrial facilities. Furthermore, the equipment can be developed and delivered more quickly, thus significantly minimizing the risk of obsolescence.

The most frequently suggested solution to the problems of equipment misuse focuses on joint utilization.[2] Centers for sharing equipment have been established in the computer and spectroscopic instrument industries. For example, the Center for Automated Spectroscopic Measurements (TsASI) was established in 1973 at the Institute of Physics, Belorussian Academy of Sciences. The TsASI's very broad mission includes conducting optical spectroscopic measurements for Belorussian

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[1] *VAN SSSR*, No. 6, 1978, p. 20.

[2] This has been suggested for several jurisdictional levels. Paton raised the possibility of establishing instrument affiliates in the republic academies (*VAN SSSR*, No. 8, 1977, p. 16). Others have proposed Academy-wide, branch, and interjurisdictional equipment centers (*VAN SSSR*, No. 3, 1978, p. 27, and No. 6, 1979, p. 15).

Academy institutes; acting as a consultant in the organization of spectroscopic research and interpretation of research results; conducting research in the field of molecular spectroscopy; organizing joint complex research with various Belorussian Academy institutes, applying modern spectroscopic and mathematical methods; and introducing molecular spectral analysis in Belorussian scientific-research institutes and industrial enterprises.[1]

The TsASI has administrative authority to control the acquisition and distribution of research equipment. It is managed by a scientific council consisting of the heads of the spectroscopic laboratories in the Institute of Physics and representatives of other scientific-research institutes. Twenty-two organizations now use its services.

As a centralized equipment support base for multiple users, the TsASI has succeeded in raising the equipment utilization factor from as low as 30 percent to 90 percent.[2] This experience and the overall concept of a cooperative center with the advantages of high-volume operation, adequate staffing of maintenance specialists, and effective information exchange make the equipment-sharing center a likely candidate for widespread introduction into the Soviet R&D network. Such centers would, however, further increase the bureaucratic complexity of the Soviet RDI structure.

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[1] *VAN SSSR*, No. 3, 1978, pp. 28-29.

[2] *VAN SSSR*, No. 8, 1977, pp. 44, 48.

V. THE R&D RESOURCES OF THE ACADEMY OF SCIENCES

The activities of the Academy of Sciences discussed in the foregoing chapters suggest that it is extensively involved in industry. To weigh the Academy's impact on the development of Soviet technology, it would be desirable to express the extent of this involvement in quantitative terms and in particular in relation to each stage of the RDI cycle.

Soviet publications contain few data that can be used directly to quantify the Academy-industry interaction. For the most part, the information must be pieced together from many sources and the estimates must be highly approximate. It is difficult to know which quantitative measure would best express the extent to which the Academy participates in the RDI cycle. Estimates of funding expenditures on basic research and applied R&D, such as Nolting's,[1] fail to answer this question, since they are based on the Soviet interpretation of the terms *basic* and *applied*. The Soviets do not clearly distinguish between research without immediate practical objectives and that directly contributing to RDI cycles. Such a distinction is essential if we are to evaluate the industrial involvement of the Academy of Sciences.

The most direct method would estimate the Academy's participation in the RDI cycle by inventorying the nature, size, and scope of the Academy's R&D projects in areas relevant to technological development. The Soviet open-source literature probably contains enough material to provide a useful, if approximate, picture in the nonmilitary field. The necessary compilation of data, however, is a tedious, long-term process requiring considerable effort.

A preliminary step towards an estimate of this kind, less direct and accurate, but more practical, consists of analyzing the physical resources of the Academy: the institutes and facilities that perform R&D. The nature, size, and importance of these resources, their specialization by field of activity, and their number in the specialized

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[1] Nolting, pp. 45-47.

fields are all significant factors that help determine the range of R&D activities open to the Academy. These R&D resources represent a dimension of the problem that complements the economic dimension with its fiscal estimates.

This chapter presents a resource survey of the Academy's R&D institutes and facilities. It must be emphasized, however, that the survey does not represent an estimate of the Academy's actual participation in the RDI cycle; at this time, it can only evaluate the capability of the Academy to participate.

A. FIELDS AND LEVELS OF R&D ACTIVITY OF ACADEMY INSTITUTES

The presidium of the Academy of Sciences, USSR, controls the network of performer institutes through four operational sections:[1]

Physico-Technical and Mathematical Sciences
Chemico-Technological and Biological Sciences
Earth Sciences
Social Sciences

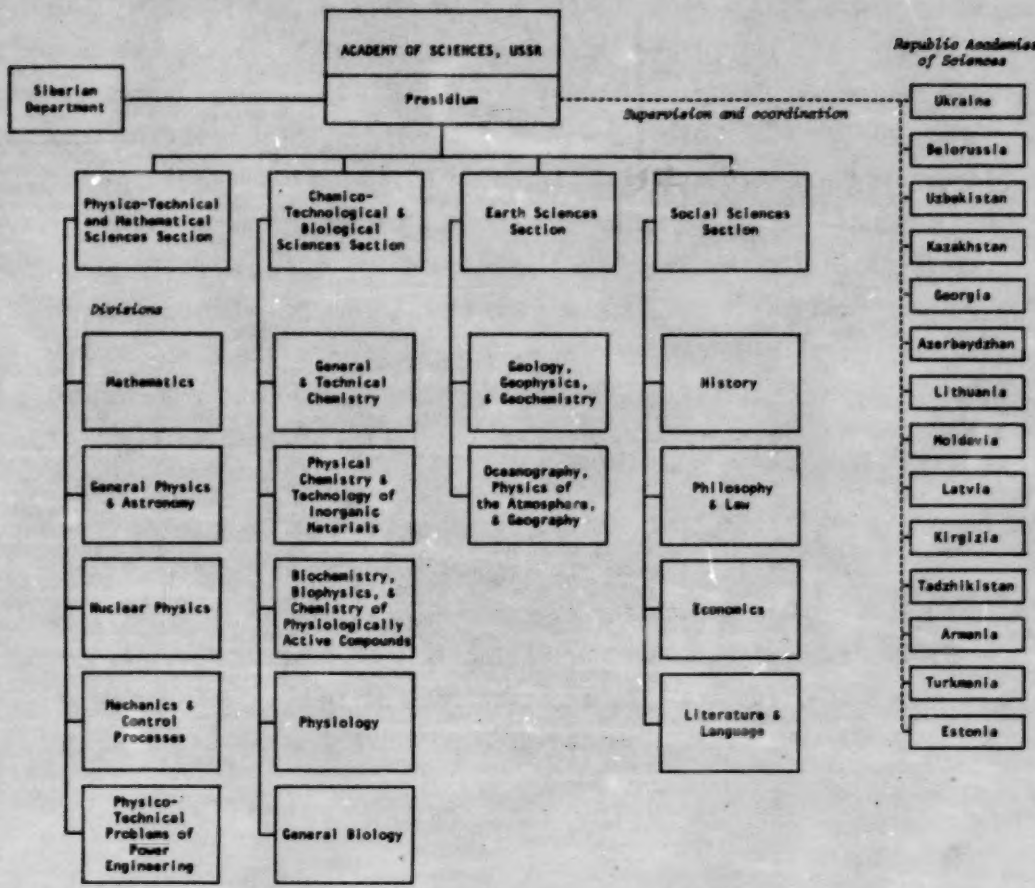
As shown in Table 1, each section administers from two to five of a total of sixteen specialized divisions, each of which controls a number of R&D institutes.

The names of the four sections indicate that three deal with areas designated in Chapter II as relevant to technological development; two of the three have the word *technical* or *technological* in their names. These qualifiers imply that the Academy of Sciences, USSR, performs significant applied research in physics and chemistry. This implication conflicts with Paragraph 2 of the Academy statutes, which lists basic research as the Academy's primary activity (see p. 13, above). One may conclude that neither the names of the presidium sections nor the Academy statutes should be taken at face value. Obviously, the Academy performs basic research in physics and chemistry, regardless of

[1] *Ustavy Akademii Nauk SSSR*, p. 176.

Table 1

ORGANIZATION OF THE ACADEMY OF SCIENCES, USSR



[a]Based on E. Zaleski et al., *Science Policy in the USSR*, Organization for Economic Cooperation and Development, Paris, 1969, and *Directory of the USSR Academy of Sciences*, Joint Publications Research Service, Arlington, Va., 1976.

the section names; on the other hand, one may question the statutory designation of Academy research in these disciplines as primarily basic.

The names of the divisions under the three relevant sections also indicate that they engage in applied research. The Physico-Technical and Mathematical Sciences Section supervises divisions of Physico-Technical Problems of Power Engineering and of Mechanics and Control Processes. The Chemico-Technological and Biological Sciences Section includes divisions of General and Technical Chemistry and of Physical Chemistry and Technology of Inorganic Materials.

A more detailed and accurate field distribution of R&D activity than can be gleaned from the presidium section and division level must be sought at the level of the individual institutes. This report develops a system of classifying Academy institutes by field of R&D activity; the classification, which differs somewhat from the organization shown in Table 1, is based on the following principles:

1. The fields are limited to the subset defined above (pp. 6 and 7) as relevant to technological development.
2. In addition to the fields, the classification system features four levels of R&D activity: general science, specialized science, engineering, and industry.
3. Each institute is assigned to a field and a level on the basis of its name.

Table 2 presents the structure of the system as a two-dimensional matrix in which the rows represent fields and the columns (except the first) represent levels. The first column lists the several broad R&D fields in which the Academy of Sciences institutes are active. The fields group the scientific disciplines and technology sectors that are usually related in the RDI cycle. The remaining columns represent the successive levels of activity of the RDI cycle. For example, basic physics is followed by applied physics, which is followed in turn by those engineering fields based directly on physics. Similarly, the science of metallurgy is followed by welding and casting engineering. The

Table 2

CLASSIFICATION OF R&D BY FIELD AND LEVEL

Field	*Level 1*	*Level 2*	*Level 3*	*Level 4*
Mathematics, Cybernetics, Instrumentation	Mathematics, cybernetics	Applied mathematics, technical cybernetics, computer centers	Automation, control systems, instruments	
Physics, Electrical Technology	Basic physics (major divisions)	Applied and specialized physics	Radio and power engineering	
Chemistry, Materials Technology	Basic chemistry (major divisions)	Specialized chemistry, metallurgy	Materials technology, welding, casting	
Geophysics	Basic geophysics, geochemistry, geography	Applied geophysics, seismology	Engineering, seismological construction, seismology	
Mineralogy and Mining		Physics and chemistry of minerals and petroleum	Mineral processing, petroleum deposits	Mining, gas utilization, diamond and petrochemical industries
Civil and Mechanical Engineering			Machine building, hydraulic engineering	
Aerospace		Space research		
Information Science and Management		S&T information processing & transmission		R&D and industrial production planning

last four fields, limited to levels 2, 3, and 4, have no direct single precursor; they have been identified separately because of their importance. Level 4 remains largely empty because the relevant activities are performed mainly by industry, which is also active to a varying extent at the other levels.

It must be noted that the assignment of the institutes to fields and levels is tentative and approximate. The assignments are expected to gain in accuracy as more detailed data become available. Institutional names are not always a reliable basis for the characterization of institutional activity. However, available information on the activity of individual institutes suggests that the field assignments are largely correct; the level assignments are less definite and may be expected to change to some extent with more complete information.

The concept of the activity level broadly relates the overall work of the institute to the stage of the RDI cycle. The concept neither assigns an institute to a particular stage nor implies that the institute engages exclusively in work at that stage. It merely suggests that an institute dealing in specialized science tends to pursue applied research more than an institute of general science and that an engineering institute is more likely to pursue applied research and development than an institute performing scientific research. Individual Academy institutes present exceptions. Some large institutes characterized as working on the general science level have major applied-research projects; conversely, engineering institutes may pursue basic research. However, the distribution of institutes by activity level is generally useful in depicting the range of R&D capabilities available in the Academy of Sciences.

B. RELATIVE IMPORTANCE OF ACADEMY INSTITUTES

The classification of Academy institutes by fields and levels leaves open the question of the individual institute's impact. The extent of the Academy's participation at each level depends not only on the number of its institutes, but also on their size and significance.

As in the case of activity levels, the lack of adequate data on the size and significance of many individual institutes imposes a

severe limitation on the possibility of discriminating among them in terms of relative impact. At this time it is possible only to attempt a crude distinction based on their regional distribution.

The regional distribution of the institutes of both the Academy of Sciences, USSR, and of the republic academies reveals two distinct groups of institutes, groups that differ from one another in importance. The first group consists of institutes of the USSR Academy, including the Siberian Department but not other regional affiliates, and institutes of the Ukrainian Academy of Sciences. The second group consists of institutes of the remaining regional affiliates of the USSR Academy and of the remaining republic academies. Most of the important research institutes of the Academy system belong to the first group. According to Duzhenkov, the largest scientific-research institutions are located in the RSFSR and in the Ukrainian SSR.[1] So is most of Soviet industry and industrial R&D. The difference between the two groups of institutes can be approximated quantitatively as follows.

Figure 2 shows the percent regional distribution of scientific workers in three sectors of employment: the Academy of Sciences system, the higher education or VUZ system, and industrial and other R&D. Data on the last two sectors are derivative (see Appendix B) and must be regarded as hypothetical.[2] The underlying assumption used in the derivation, that the number of VUZ scientific workers in a republic is proportional to the VUZ budget for that republic, may not be valid in all cases. Nevertheless, the data provide a reasonable regional ranking within the second group, in which the Transcaucasian and Baltic republics lead the Central Asian republics in terms of industrial R&D activity.

The most consistent difference between the RSFSR-Ukraine and the rest of the republics appears in the share of the academies of sciences

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[1] Duzhenkov, p. 175.

[2] The category of "scientific workers" in Soviet statistical publications includes two main groups: teachers at higher educational institutions and persons performing R&D. The category is also defined as pertaining to all persons with an advanced degree or academic title (whether performing R&D or not) and persons without degrees actually performing research. Published statistics provide scientific worker distribution by republic and by the academies of sciences, but do not differentiate between teachers and R&D performers. See: Nancy Nimitz, *The Structure of*

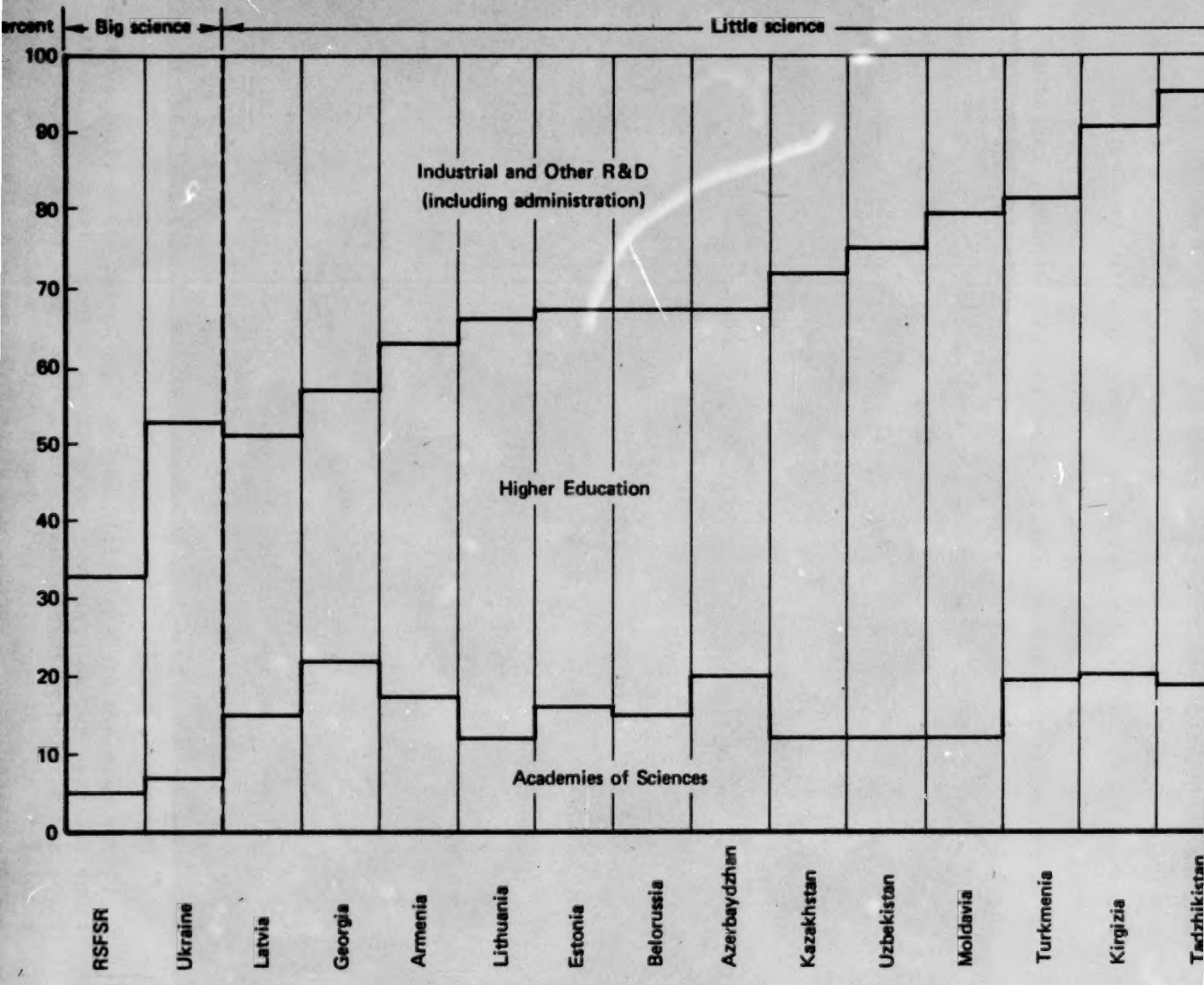

Fig. 2 — Relative distribution of scientific workers, 1975

(Based on Appendix B, p. 73; includes fields not relevant to technological development)

in the total population of scientific workers; in the second group the share is larger by a factor of 2 to 3 than in the first. As the share of industrial R&D decreases, the scientific workers of the second group are increasingly represented by educators.

Figure 2 confirms the industrial concentration in the RSFSR and the Ukraine. The USSR ratios of scientific workers in the three sectors are close to those of the RSFSR and the Ukraine (see Appendix Table B.2). The ratios for most of the republics of the second group are quite different, with both Academy and VUZ workers playing a larger role than industrial R&D workers.

The Academy of Sciences appears to play a different role in each of the two regional groups. In the first group, the Academy is part of a large R&D activity including a strong industrial component. In the second group, the Academy has less opportunity to interact with industry. In the absence of an adequate industrial environment, the local Academy may compensate by expanding its own development facilities, or it may emphasize basic research. The following analysis shows that most republic academies adopt the latter alternative. One can also expect that most R&D projects of national importance are assigned to the academies of the first group, while academies of the second group deal mainly with local projects.

The following analysis of Academy R&D institutes reflects the distinction between the two groups, as well as the breakdown by fields and levels. For this purpose, the R&D institutions of the Academy system falling into the first group are designated "Big Science," those of the second group, "Little Science." These designations are approximate and subject to exceptions. Some Academy institutes in the Little Science group perform R&D work that may have national significance. Some Big Science institutes may be limited to work of local significance. The RSFSR, represented by the Academy of Sciences, USSR, forms the main component of Big Science. However, the regional affiliates of the USSR

Soviet Outlays on R&D in 1960 and 1968, The Rand Corporation, R-1207-DDRE, 1974, p. 19. See also: Thomas P. Kridler, *Soviet Professional Scientific and Technical Manpower*, U.S. Air Force, Air Force Systems Command, Foreign Technology Division, ST-CS-01-49-72, 1972, p. 55.

Academy, except for the Siberian Department, play a role similar to that of the smaller republic academies and are therefore included in the Little Science group.[1]

Table 3 shows the distribution of research institutes of the USSR and republic academies of sciences, including institutes that are both relevant and not relevant to technological development. The Big Science relevant institutes number 154, or close to one-third of all Academy institutes. The importance of the Academy to the development of technology is illustrated by the fact that nearly twice as many institutes are relevant to that development than are not relevant.

Table 3

DISTRIBUTION OF ACADEMY RESEARCH INSTITUTES, 1976-1978
(In numbers of institutes and percentages)

	Big Science		Little Science		Total	
	No.	%	No.	%	No.	%
Relevant to technological development	154	66	177	62	331	64
Not relevant to technological development	78	34	107	38	185	36
Total	232		284		516[a]	

SOURCE: "Directory of Soviet Research Organizations" and "Directory of the USSR Academy of Sciences," *VAN SSSR*, No. 1, 1978, p. 158; No. 3, 1978, p. 119; No. 4, 1978, p. 136. Breakdown according to Appendix A.

[a]Does not include libraries, botanical gardens, museums, etc., which are included in Soviet statistics on research institutions, as distinct from research institutes. At the end of 1976, the Academy of Sciences, USSR, and the republic academies had a total of 612 research institutions. *Narodnoye khozyaystvo SSSR za 60 let* (National Economy of the USSR During 60 Years), Moscow, 1977, p. 144.

C. CLASSIFICATION OF R&D INSTITUTES OF THE ACADEMY OF SCIENCES SYSTEM

Appendix A classifies institutes of the USSR and republic academies by field, level, and importance. Based on a count of these institutes, Table 4 adds to Table 2 the number of Academy institutes in Big and

[1]The exclusion of the regional affiliates of the USSR Academy of Sciences is not reflected in the statistical data for scientific workers

Table 4

NUMBER OF ACADEMY INSTITUTES IN BIG AND LITTLE SCIENCE, BY FIELD AND LEVEL 1976-1978

Field and Number of Institutes	*Level 1*	*Level 2*	*Level 3*	*Level 4*
Mathematics, Cybernetics, Instrumentation	Mathematics, cybernetics	Applied mathematics, technical cybernetics, computer centers	Automation, control systems, instruments	
Big Science	9	6	8	
Little Science	17	7	5	
Physics, Electrical Technology	Basic physics (major divisions)	Applied and specialized physics	Radio and power engineering	
Big Science	16	28	5	
Little Science	18	19	7	
Chemistry, Materials Technology	Basic chemistry (major divisions)	Specialized chemistry, metallurgy	Materials technology, welding, casting	
Big Science	15	11	7	
Little Science	25	11	7	
Geophysics	Basic geophysics, geochemistry, geography	Applied geophysics, seismology	Engineering, seismological construction, seismology	
Big Science	14	11	2	
Little Science	35	8	4	
Mineralogy and Mining		Physics and chemistry of minerals and petroleum	Mineral processing, petroleum deposits	Mining, gas utilizatic diamond and petrochemical industri
Big Science		4	4	3
Little Science		2	3	5
Civil and Mechanical Engineering			Machinebuilding, hydraulic engineering	
Big Science			5	
Little Science			4	
Aerospace		Space research		
Big Science		1		
Little Science		0		
Information Science and Management		S&T information processing & transmission		R&D and industrial production planning
Big Science		2		3
Little Science		0		0

Little science in each field and at each level. Table 5 summarizes the statistical data of Table 4.

Table 5

DISTRIBUTION OF ACADEMY INSTITUTES, 1976-1978: SUMMARY
(In numbers of institutes and percentages)

	Big Science			Little Science			Total	
Level	No.	%		No.	%		No.	%
1	54	35		95	54		149	45
2	63	41	65	47	26	46	110	33
3	31	20		30	17		61	18
4	6	4		5	3		11	3
Total	154	47		177	53		331	

The data show that two-thirds of all Big Science institutes are in applied science and engineering. Less than one-half of Little Science institutes fall into these areas. The remaining Little Science institutes research the broad major divisions of basic mathematics, physics, chemistry, and geophysics. While a significant number of Little Science institutes engage in the solution of regional problems, the main role of Little Science appears to be the pursuit of general science, that is, research that in the West is pursued by universities.

The concentration of industrial R&D in the Big Science regions becomes strikingly apparent when we consider the distribution of scientific workers between the two regional groups. Table 6 shows that, outside the Academy system and universities, over 90 percent of all scientific workers are employed in Big Science. Academy system scientific workers show a smaller difference between Big and Little science.

Big Science appears strongest in the applied and specialized fields of physics and chemistry, such as physics of high and low temperatures, high pressures, metals and semiconductors, acoustics, chemistry of combustion, metallurgy, electrochemistry, and high molecular compounds.

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shown elsewhere in this report. In these data, Big Science is identified roughly with RSFSR and the Ukraine.

Table 6

PERCENT DISTRIBUTION OF SCIENTIFIC WORKERS BETWEEN BIG AND LITTLE SCIENCE, 1975[a]

	Academy of Sciences	VUZ	Industrial and Other
Big Science	62	74	91
Little Science	38	26	9

[a]From Table B.1, cols. 3, 4, and 5; represents all fields, including those not relevant to technological development.

The list of specialized institutes in these two fields suggests a well-developed, comprehensive capability for research leading to advanced technologies. It is clear that the physics and chemistry institutes, amounting to nearly one-half of Big Science, represent the core of the Academy's R&D forces dedicated to technological development.

Mathematics and cybernetics, the latter extending from mathematical machines to automation, are next in strength in Big Science. The fact that nearly 15 percent of Big Science institutes work with these topics indicates the importance of these topics to the Academy. Little Science is particularly strong in basic mathematics and basic chemistry, and much stronger than Big Science in the entire field of geophysics. While this last strength could be expected in view of the regional significance of many geophysical topics, it is surprising to find Little Science focusing mainly on basic geophysics, rather than on its applied, specialized, and engineering disciplines.

The Academy is weaker in engineering than in scientific research, and is particularly weak in both the scientific and engineering aspects of aerospace. Only one Academy institute specializes in space research. Although some of the physics and materials technology institutes of the Academy perform relevant work on thermodynamics, fluid mechanics, aerodynamics, strength of materials, etc., no specialized aeronautics research institutes are in evidence.

VI. CONCLUSIONS

The present preliminary study concludes that:

- The future of Soviet technology depends significantly on the Academy of Sciences.
- Severe problems stemming from its nature and its relationship with Soviet industry encumber the Academy's ability to serve Soviet technology.

The Soviet Academy of Sciences is a unique institution without counterpart in other technologically advanced countries. Its scientific eminence in the USSR derives from the fact that it concentrates the top scientific talent of the country, it is simultaneously a planner, manager, and an independent performer of R&D of national importance, and it is generally regarded as the ultimate source of technological progress.

The Academy's role as a developer of advanced technologies emerges clearly from the discussions among Soviet R&D and industrial leaders, as well as from the present study of the Academy's R&D resources. The discussions reveal a considerable degree of unanimity about several major aspects of technological development and the Academy's mission. According to the Soviet view: (1) science is the prime mover of technology--as both the necessary theoretical foundation and the immediate stimulus of technological breakthroughs; (2) science, and the Academy, can be expected to help solve the chronic problems of Soviet industrial innovation (presumably by providing ingenious technological shortcuts); (3) the Academy's network of R&D institutes should cooperate actively with industrial organizations throughout the innovation process; (4) these activities must not be allowed to detract from the Academy's primary mission of pursuing basic research.

The last view reveals a measure of conflict in the perception of the priorities that govern the Academy's mission. The configuration

of the Academy's R&D resources indicates how this conflict is being resolved in practice. While the Academy as a whole reflects the priority of basic research, this is not necessarily true of specific parts of the Academy's structure. The analysis in this study of the relevant fields and major institutes of the Academy showed that the Academy departed considerably from the basic-research orientation. One-third of all Academy institutes are major R&D facilities, concentrated in the RSFSR and Ukraine, and active in fields relevant to technological development. This group, called here Soviet Big Science, is oriented toward applied research, development, and active aid to innovation. Since the Big Science institutes are generally larger than other institutes, the fraction of the Academy that (1) fosters technology and (2) participates in various stages of the RDI cycle probably far exceeds one-third.

The applied-research and development configuration of Big Science is strongest in the specialized fields of physics and chemistry, which serve the industrially and militarily significant technologies of solid state, optics, high-density energy converters, metals, alloys, etc.

The effectiveness of the Academy's contribution to technological development depends wholly on its successful cooperation with industry. The Academy is not equipped to handle the entire RDI cycle, and in particular, it lacks extensive test and pilot production facilities. At present, the Siberian Department of the Academy of Sciences, USSR, and the Ukrainian Academy of Sciences are making the most comprehensive attempts to participate in the RDI cycle. While these efforts may be regarded as a showcase of scientific-industrial integration, they have not solved the major problem of overcoming the organizational distance between the Academy and industry.

According to B. Ye. Paton, the architect of the Ukrainian effort, to be effective, the entire RDI cycle must be spanned by a single management or, preferably, by a single performer organization. One could conceive of a range of possible schemes to meet Paton's requirement. At one extreme of this range, the Academy would accelerate the acquisition of industrial-type facilities until it became an industrial enterprise in its own right. However, this would contradict the main mission and

statute of the Academy. At the other extreme, a part of the Academy would merge with the existing industrial ministry system. The history of the Academy following the 1961 transfer of some institutes to industry demonstrates the failure of this approach.

The Academy of Sciences is more than the sum of its institutes. The Soviets have faith in the collective strength of science embodied in an Academy that is independent of the individual institutes and that cannot be duplicated in the environment of the individual ministries. Thus, neither of the above extremes is likely to materialize, and the Soviets will probably continue to live with the organizational separation between the Academy and the ministries and to patch rather than rebuild the system. The bureaucratic patchwork representing the diverse types of research-production organizations continues to exhibit the same lack of common interests and incentives that characterized the participants before they were brought together.

This study indicates a large spectrum of Academy-dependent technologies that are increasingly important to industry and defense. As long as the Academy is not adequately integrated into the RDI cycle, the future effective development of these technologies will remain in question.

Appendix A

INSTITUTES OF THE USSR ACADEMY OF SCIENCES AND REPUBLIC ACADEMIES, CLASSIFIED BY FIELD, LEVEL, AND SIGNIFICANCE

MATHEMATICS, CYBERNETICS, AND INSTRUMENTATION

LEVEL 1

Big Science

Steklov Institute of Mathematics, Moscow
Academy of Sciences, USSR

Steklov Institute of Mathematics, Leningrad
Academy of Sciences, USSR

Institute of Mathematics, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Mathematics, Krasnoyarsk
Siberian Department, Academy of Sciences, USSR

Institute of Mathematics, Kiev
Academy of Sciences, Ukrainian SSR

Central Institute of Economic Mathematics, Moscow
Academy of Sciences, USSR

Central Institute of Economic Mathematics, Leningrad
Academy of Sciences, USSR

Institute of Cybernetics, Kiev
Academy of Sciences, Ukrainian SSR

Grashchenkov Laboratory of Problems of Control of Human and Animal Organisms, Moscow
Academy of Sciences, USSR

Little Science

Institute of Mathematics, Yerevan
Academy of Sciences, Armenian SSR

Institute of Mathematics, Minsk
Academy of Sciences, Belorussian SSR

Razmadze Institute of Mathematics, Tbilisi
Academy of Sciences, Georgian SSR

Komanovskiy Institute of Mathematics, Tashkent
Academy of Sciences, Uzbek SSR

Institute of Mathematics, Kazan'
Kazan' Affiliate, Academy of Sciences, USSR

Institute of Mathematics and Cybernetics, Vil'nyus
Academy of Sciences, Lithuanian SSR

Institute of Mathematics and Mechanics, Baku
Academy of Sciences, Azerbaydzhan SSR

Institute of Mathematics and Mechanics, Alma Ata
Academy of Sciences, Kazakh SSR

Institute of Mathematics and Mechanics, Sverdlovsk
Ural Scientific Center, Academy of Sciences, USSR

Institute of Mathematics and Computer Center, Kishinev
Academy of Sciences, Moldavian SSR

Institute of Mathematics and Computer Center, Dushanbe
Academy of Sciences, Tadzhik SSR

Institute of Cybernetics, Baku
Academy of Sciences, Azerbaydzhan SSR

Institute of Cybernetics, Tallin
Academy of Sciences, Estonian SSR

Institute of Cybernetics, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Cybernetics and Computer Center, Tashkent
Academy of Sciences, Uzbek SSR

Yerevan Scientific Research Institute of Mathematical Machines,
Yerevan
Academy of Sciences, Armenian SSR

Institute of Adaptive Systems, Kafan
Academy of Sciences, Armenian SSR

LEVEL 2

Big Science

Institute of Applied Mathematics, Moscow
Academy of Sciences, USSR

Institute of Applied Mathematics and Mechanics, Donetsk
Academy of Sciences, Ukrainian SSR

Computer Center, Moscow
Academy of Sciences, USSR

Computer Center, Pushchino
Academy of Sciences, USSR

Leningrad Scientific Research Computer Center, Leningrad
Academy of Sciences, USSR

Computer Center, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Little Science

Institute of Technical Cybernetics, Minsk
Academy of Sciences, Belorussian SSR

Institute of Technical Cybernetics, Sverdlovsk
Academy of Sciences, USSR

Joint Computer Center, Yerevan
Academy of Sciences, Armenian SSR

Computer Center, Minsk
Academy of Sciences, Belorussian SSR

Computer Center, Tbilisi
Academy of Sciences, Georgian SSR

Computer Center, Krasnoyarsk
Siberian Department, Academy of Sciences, USSR

Institute of Electronics, Minsk
Academy of Sciences, Belorussian SSR

LEVEL 3

Big Science

Lebedev Institute of Precision Mechanics and Computation Techniques, Moscow
Academy of Sciences, USSR

Institute of Control Problems, Moscow
Academy of Sciences, USSR

Institute of Control Problems, Leningrad
Academy of Sciences, USSR

Institute of Automation, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Automation and Electrometry, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Special Design Bureau of Analytical Instrument Building, Leningrad
Academy of Sciences, USSR

Institute of Analytic Instrumentation [location unknown]
Academy of Sciences, USSR

Electron Microscopy Laboratory, Moscow
Academy of Sciences, USSR

Little Science

Institute of Automation, Frunze
Academy of Sciences, Kirgiz SSR

Institute of Automation and Control Processes, Vladivostok
Academy of Sciences, USSR

Scientific-Research Institute of Automation of Production Processes, Kirovakan
Academy of Sciences, Armenian SSR

Institute of Control Systems, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Electronics and Computing Technology, Riga
Academy of Sciences, Latvian SSR

PHYSICS AND ELECTRICAL TECHNOLOGY

LEVEL 1

Big Science

Lebedev Institute of Physics, Moscow
Academy of Sciences, USSR

Kirenskiy Institute of Physics, Krasnoyarsk
Siberian Department, Academy of Sciences, USSR

Institute of Physics, Kiev
Academy of Sciences, Ukrainian SSR

Landau Institute of Theoretical Physics, Chernogolovka
Academy of Sciences, USSR

Institute of Theoretical Physics, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Mechanics, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Mechanics, Dnepropetrovsk
Academy of Sciences, Ukrainian SSR

Institute of Mechanics, Khar'kov
Academy of Sciences, Ukrainian SSR

Institute of Problems of Mechanics, Moscow
Academy of Sciences, USSR

Vavilov Institute of Physical Problems, Moscow
Academy of Sciences, USSR

Konstantinov Institute of Nuclear Physics, Leningrad
Academy of Sciences, USSR

Institute of Nuclear Physics, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Nuclear Research, Kresty
Academy of Sciences, USSR

Nuclear Research Institute, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Solid-State Physics, Moscow
Academy of Sciences, USSR

Institute of Chemical Physics, Moscow
Academy of Sciences, USSR

Little Science

Research Institute of Physics, Yerevan
Academy of Sciences, Armenian SSR

Yerevan Institute of Physics, Yerevan
Academy of Sciences, Armenian SSR

Institute of Physics, Mogilev
Academy of Sciences, Belorussian SSR

Institute of Physics, Minsk
Academy of Sciences, Belorussian SSR

Institute of Physics, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Physics, Salaspils
Academy of Sciences, Latvian SSR

Institute of Physics, Vil'nyus
Academy of Sciences, Lithuanian SSR

Institute of Physics, Makhachkala
Dagestan Affiliate, Academy of Sciences, USSR

Institute of Mechanics, Yerevan
Academy of Sciences, Armenian SSR

Institute of Mechanics and Computer Center, Tashkent
Academy of Sciences, Uzbek SSR

Institute of Nuclear Physics, Alma Ata
Academy of Sciences, Kazakh SSR

Institute of Nuclear Physics, Riga
Academy of Sciences, Latvian SSR

Institute of Nuclear Physics, Ulugbek
Academy of Sciences, Uzbek SSR

Institute of Solid-State Physics, Baku
Academy of Sciences, Azerbaydzhan SSR

Chemical Physics Laboratory, Yerevan
Academy of Sciences, Armenian SSR

Institute of Solid-State Physics and Semiconductors, Minsk
Academy of Sciences, Belorussian SSR

Institute of High-Energy Physics, Alma Ata
Academy of Sciences, Kazakh SSR

Institute of Physics, Mathematics and Mechanics, Frunze
Academy of Sciences, Kirgiz SSR

LEVEL 2

Big Science

Institute of Applied Physics, Gor'kiy
Academy of Sciences, USSR

Physico-Technical Research Institute, Obninsk
Academy of Sciences, USSR

Ioffe Physico-Technical Institute, Leningrad
Academy of Sciences, USSR

Ukrainian Physico-Technical Institute, Khar'kov
Academy of Sciences, Ukrainian SSR

Donetsk Physico-Technical Institute, Donetsk
Academy of Sciences, Ukrainian SSR

Institute of Theoretical and Applied Mechanics, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Physico-Mechanics, L'vov
Academy of Sciences, Ukrainian SSR

Institute of Semiconductors, Leningrad
Academy of Sciences, USSR

Institute of Semiconductors, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Semiconductor Physics, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Spectroscopy, Krasnaya Pakhra
Academy of Sciences, USSR

Shubnikov Institute of Crystallography, Moscow
Academy of Sciences, USSR

Institute of Acoustics, Moscow
Academy of Sciences, USSR

Institute of Acoustics, Sukhumi
Academy of Sciences, USSR

Institute of High Temperatures, Moscow
Academy of Sciences, USSR

Institute of Thermophysics, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Technical Thermophysics, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Physics of High Pressures, Krasnaya Pakhra
Academy of Sciences, USSR

Institute of Hydrodynamics, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Hydromechanics, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Physics of Metals, Sverdlovsk
Academy of Sciences, USSR

Institute of Metal Physics, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Atmospheric Optics, Tomsk
Siberian Department, Academy of Sciences, USSR

Institute of Radiophysics and Electronics, Khar'kov
Academy of Sciences, Ukrainian SSR

Khlopin Institute of Radium, Leningrad
Academy of Sciences, USSR

Institute of Photosynthesis, Pushchino
Academy of Sciences, USSR

Physico-Technical Institute of Low Temperatures, Khar'kov
Academy of Sciences, Ukrainian SSR

Institute of Electrodynamics, Kiev
Academy of Sciences, Ukrainian SSR

Little Science

Institute of Applied Physics, Minsk
Academy of Sciences, Belorussian SSR

Institute of Applied Physics, Kishinev
Academy of Sciences, Moldavian SSR

Physico-Technical Institute, Yerevan
Academy of Sciences, Armenian SSR

Physico-Technical Institute, Minsk
Academy of Sciences, Belorussian SSR

Physico-Technical Institute, Sukhumi
Academy of Sciences, Georgian SSR

Umarov Physico-Technical Institute, Dushanbe
Academy of Sciences, Tadzhik SSR

Turkmen Physico-Technical Institute, Ashkhabad
Academy of Sciences, Turkmen SSR

Physico-Technical Institute, Tashkent
Academy of Sciences, Uzbek SSR

Physico-Technical Institute, Kazan'
Kazan' Affiliate, Academy of Sciences, USSR

Institute of Physics of Semiconductors, Vil'nyus
Academy of Sciences, Lithuanian SSR

Institute of Thermophysics, Alma Ata
Academy of Sciences, Kazakh SSR

Institute of Hydrodynamics, Alma Ata
Academy of Sciences, Kazakh SSR

Institute of Radiophysics and Electronics, Ashtarak
Academy of Sciences, Armenian SSR

Institute of Heat and Mass Transfer, Minsk
Academy of Sciences, Belorussian SSR

Institute of Thermophysics and Electrophysics, Tallin
Academy of Sciences, Estonian SSR

Physico-Energetics Institute, Riga
Academy of Sciences, Latvian SSR

Byurakan Optical and Mechanical Laboratory, Byurakan
Academy of Sciences, Armenian SSR

Institute of Electronics, Tashkent
Academy of Sciences, Uzbek SSR

Institute of Electronics, Minsk
Academy of Sciences, Belorussian SSR

LEVEL 3

Big Science

Institute of High-Current Electronics, Tomsk
Siberian Department, Academy of Sciences, USSR

High-Energy Semiconductor Laser Laboratory, Krasnaya Pakhra
Academy of Sciences, USSR

Institute of Radio Engineering, Moscow
Academy of Sciences, USSR

Institute of Radio Engineering and Electronics, Moscow
Academy of Sciences, USSR

Siberian Institute of Power Engineering, Irkutsk
Siberian Department, Academy of Sciences, USSR

Little Science

Armenian Scientific Research Institute of Power Engineering, Yerevan
Academy of Sciences, Armenian SSR

Institute of Power Engineering, Alma Ata
Academy of Sciences, Kazakh SSR

Yesman Institute of Power Engineering, Baku
Academy of Sciences, Azerbaydzhan SSR

Institute of Physical and Technical Problems of Power Engineering, Kaunas
Academy of Sciences, Lithuanian SSR

Institute of Power Engineering and Automation, Tashkent
Academy of Sciences, Uzbek SSR

Institute of Nuclear Power Engineering, Minsk
Academy of Sciences, Belorussian SSR

Atomic Research Center, Tashkent
Academy of Sciences, Uzbek SSR

CHEMISTRY AND MATERIALS TECHNOLOGY

LEVEL 1

Big Science

Institute of Chemistry, Gor'kiy
Academy of Sciences, USSR

Scientific Research Institute of Chemistry, Elektrostal'
Academy of Sciences, USSR

Kurnakov Institute of General and Inorganic Chemistry, Moscow
Academy of Sciences, USSR

Institute of General and Inorganic Chemistry, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Inorganic Chemistry, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Physical Chemistry, Moscow
Academy of Sciences, USSR

Pisarzhevskiy Institute of Physical Chemistry, Kiev
Academy of Sciences, Ukrainian SSR

Zelinskiy Institute of Organic Chemistry, Moscow
Academy of Sciences, USSR

Institute of Organic Chemistry, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Organic Chemistry, Kiev
Academy of Sciences, Ukrainian SSR

Arbuzov Institute of Organic and Physical Chemistry, Kazan'
Academy of Sciences, USSR

Institute of Element-Organic Compounds, Moscow
Academy of Sciences, USSR

Institute of Biochemistry, Kiev
Academy of Sciences, Ukrainian SSR

Bakh Institute of Biochemistry, Moscow
Academy of Sciences, USSR

Institute of New Chemical Problems, Moscow
Academy of Sciences, USSR

Little Science

Institute of Chemistry, Tallin
Academy of Sciences, Estonian SSR

Institute of Chemistry, Riga
Academy of Sciences, Latvian SSR

Institute of Chemistry, Kishinev
Academy of Sciences, Moldavian SSR

Institute of Chemistry, Dushanbe
Academy of Sciences, Tadzhik SSR

Institute of Chemistry, Ashkhabad
Academy of Sciences, Turkmen SSR

Institute of Chemistry, Krasnoyarsk
Siberian Department, Academy of Sciences, USSR

Institute of Chemistry, Tashkent
Academy of Sciences, Uzbek SSR

Institute of Chemistry, Ufa
Bashkir Affiliate, Academy of Sciences, USSR

Institute of Chemistry, Vladivostok
East Siberian Affiliate, Academy of Sciences, USSR

Institute of Chemistry, Sverdlovsk
Ural Scientific Center, Academy of Sciences, USSR

Institute of General and Inorganic Chemistry, Yerevan
Academy of Sciences, Armenian SSR

Institute of General and Inorganic Chemistry, Minsk
Academy of Sciences, Belorussian SSR

Institute of Inorganic Chemistry, Riga
Academy of Sciences, Latvian SSR

Institute of Organic Chemistry, Yerevan
Academy of Sciences, Armenian SSR

Institute of Organic Chemistry, Frunze
Academy of Sciences, Kirgiz SSR

Institute of Organic Chemistry, Irkutsk
East Siberian Affiliate, Academy of Sciences, USSR

Institute of Physical and Organic Chemistry, Minsk
Academy of Sciences, Belorussian SSR

Institute of Physical and Organic Chemistry, Tbilisi
Academy of Sciences, USSR

Institute of Biochemistry, Yerevan
Academy of Sciences, Armenian SSR

Institute of Biochemistry, Vil'nyus
Academy of Sciences, Lithuanian SSR

Institute of Biochemistry, Ulugbek
Academy of Sciences, Uzbek SSR

Institute of Fine Organic Chemistry, Yerevan
Academy of Sciences, Armenian SSR

Institute of Inorganic and Physical Chemistry, Baku
Academy of Sciences, Azerbaydzhan SSR

Institute of Inorganic and Physical Chemistry, Frunze
Academy of Sciences, Kirgiz SSR

Institute of Chemical Sciences, Alma Ata
Academy of Sciences, Kazakh SSR

LEVEL 2

Big Science

Institute of Electrochemistry, Moscow
Academy of Sciences, USSR

Institute of Catalysis, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Chemical Kinetics and Combustion, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Colloidal and Hydrochemistry, Kiev
Academy of Sciences, Ukrainian SSR

Vernadskiy Institute of Geochemistry and Analytical Chemistry, Moscow
Academy of Sciences, USSR

Shemyakin Institute of Bioorganic Chemistry, Moscow
Academy of Sciences, USSR

Baykov Institute of Metallurgy, Moscow
Academy of Sciences, USSR

Institute of Chemistry and Metallurgy, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Ferrous Metallurgy, Donetsk
Academy of Sciences, Ukrainian SSR

Institute of High-Molecular Compounds, Leningrad
Academy of Sciences, USSR

Institute of Chemistry of High-Molecular Compounds, Kiev
Academy of Sciences, Ukrainian SSR

Little Science

Institute of Electrochemistry, Sverdlovsk
Ural Scientific Center, Academy of Sciences, USSR

Institute of Metallurgy, Sverdlovsk
Ural Scientific Center, Academy of Sciences, USSR

Institute of Metallurgy, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Chemistry and Metallurgy, Karaganda
Academy of Sciences, Kazakh SSR

Institute of Ferrous Metallurgy, Karaganda
Academy of Sciences, Kazakh SSR

Institute of Applied Inorganic Chemistry and Electrochemistry, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Chemistry of Additives, Baku
Academy of Sciences, Azerbaydzhan SSR

Scientific-Research Institute of Organic Catalysis and Electrochemistry, Alma Ata
Academy of Sciences, Kazakh SSR

Institute of Organic Synthesis, Riga
Academy of Sciences, Latvian SSR

Institute of Metallurgy and Ore Dressing, Alma Ata
Academy of Sciences, Kazakh SSR

Pacific Institute of Bioorganic Chemistry, Vladivostok
Far Eastern Scientific Center, Academy of Sciences, USSR

LEVEL 3

Big Science

Stabilization of Polymers Laboratory, Gor'kiy
Academy of Sciences, USSR

Grebenshchikov Institute of Chemistry of Silicates, Leningrad
Academy of Sciences, USSR

Dnepropetrovsk Scientific Research Institute of Coal Chemistry, Dnepropetrovsk
Academy of Sciences, Ukrainian SSR

Institute of Superhard Materials, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Problems of Materials Science, Kiev
Academy of Sciences, Ukrainian SSR

Paton Institute of Electric Welding, Kiev
Academy of Sciences, Ukrainain SSR

Institute of Problems of Casting, Kiev
Academy of Sciences, Ukrainian SSR

Little Science

Institute of Wood Chemistry, Riga
Academy of Sciences, Latvian SSR

Institute of Chemistry and Chemistry Technology, Vil'nyus
Academy of Sciences, Lithuanian SSR

Institute of Theoretical Problems of Chemical Technology, Baku
Academy of Sciences, Azerbaydzhan SSR

Gomel' Institute of Mechanics of Metal Polymer Systems, Gomel'
Academy of Sciences, Belorussian SSR

Institute of Mechanics of Machines and Polymer Materials, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Polymer Mechanics, Riga
Academy of Sciences, Latvian SSR

Scientific Research Institute of Chemistry and Technology of Cotton Cellulose, Tashkent
Academy of Sciences, Uzbek SSR

GEOPHYSICS

LEVEL 1

Big Science

Tyumen' Institute of Geophysics, Tyumen'
Academy of Sciences, USSR

Institute of Geophysics, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Geophysics, L'vov
Academy of Sciences, Ukrainian SSR

Institute of Geology, Moscow
Academy of Sciences, USSR

Institute of Geology and Geophysics, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Geological Sciences, Kiev
Academy of Sciences, Ukrainian SSR

Shmidt Institute of Physics of the Earth, Moscow
Academy of Sciences, USSR

Institute of Problems of Multidisciplinary Studies of the Earth, Moscow
Academy of Sciences, USSR

Institute of Physics of the Atmosphere, Moscow
Academy of Sciences, USSR

Institute of Geology and Geochronology of the Precambrian Era, Leningrad
Academy of Sciences, USSR

Alpine Institute of Geophysics, Nal'chik
Academy of Sciences, USSR

Institute of the Subarctic, Leningrad
Academy of Sciences, USSR

Institute of Limnology, Leningrad
Academy of Sciences, USSR

Institute of Geography, Moscow
Academy of Sciences, USSR

Little Science

Institute of Geophysics, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Geophysics, Sverdlovsk
Ural Scientific Center, Academy of Sciences, USSR

Gubkin Institute of Geology, Baku
Academy of Sciences, Azerbaydzhan SSR

Institute of Geology, Tallin
Academy of Sciences, Estonian SSR

Institute of Geology, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Geology, Frunze
Academy of Sciences, Kirgiz SSR

Institute of Geology, Dushanbe
Academy of Sciences, Tadzhik SSR

Institute of Geology, Ashkhabad
Academy of Sciences, Turkmen SSR

Institute of Geology, Yakutsk
Yakutsk Affiliate, Academy of Sciences, USSR

Institute of Geology, Ufa
Bashkir Affiliate, Academy of Sciences, USSR

Institute of Geology, Ulan Ude
Buryat Affiliate, Academy of Sciences, USSR

Institute of Geology, Makhachkala
Dagestan Affiliate, Academy of Sciences, USSR

Institute of Geology, Kazan'
Kazan' Affiliate, Academy of Sciences, USSR

Institute of Geology, Kirovsk
Kola Affiliate, Academy of Sciences, USSR

Institute of Geology, Syktyvkar
Komi Affiliate, Academy of Sciences, USSR

Far Eastern Institute of Geology, Vladivostok
Far Eastern Scientific Center, Academy of Sciences, USSR

Karelian Institute of Geology, Petrozavodsk
Karelian Affiliate, Academy of Sciences, USSR

Institute of Geology and Geophysics, Kishinev
Academy of Sciences, Moldavian SSR

Abdullayev Institute of Geology and Geophysics, Tashkent
Academy of Sciences, Uzbek SSR

Institute of Geological Sciences, Yerevan
Academy of Sciences, Armenian SSR

Satpayev Institute of Geological Sciences, Alma Ata
Academy of Sciences, Kazakh SSR

Institute of Limnology, Irkutsk
Siberian Department, Academy of Sciences, USSR

Institute of Geography, Baku
Academy of Sciences, Azerbaydzhan SSR

Vakhushti Institute of Geography, Tbilisi
Academy of Sciences, Georgian SSR

Institute of Geochemistry and Geophysics, Minsk
Academy of Sciences, Belorussian SSR

Institute of Geology and Geography, Vil'nyus
Academy of Sciences, Lithuanian SSR

Vinogradov Institute of Geochemistry, Irkutsk
East Siberian Affiliate, Academy of Sciences, USSR

Institute of Geology and Geochemistry, Sverdlovsk
Ural Scientific Center, Academy of Sciences, USSR

Institute of Physics of the Earth and Atmosphere, Ashkhabad
Academy of Sciences, Turkmen SSR

Institute of the Earth's Crust, Irkutsk
East Siberian Affiliate, Academy of Sciences, USSR

Institute of Space Physics Research and Aeronomy, Yakutsk
Yakutsk Affiliate, Academy of Sciences, USSR

Institute of Tectonics and Geophysics, Khabarovsk
Far Eastern Scientific Center, Academy of Sciences, USSR

Institute of Volcanology, Petropavlovsk-Kamchatskiy
Far Eastern Scientific Center, Academy of Sciences, USSR

Institute of Geography of Siberia and the Far East, Irkutsk
East Siberian Affiliate, Academy of Sciences, USSR

Pacific Ocean Institute of Geography, Vladivostok
Far Eastern Scientific Center, Academy of Sciences, USSR

LEVEL 2

Big Science

Scientific Research Institute of Applied Geodesy, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Geology and Geochemistry of Combustible Materials, L'vov
Academy of Sciences, Ukrainian SSR

Institute of Marine Hydrophysics, Sevastopol'
Academy of Sciences, Ukrainian SSR

Institute of Marine Hydrophysics, Simeiz
Academy of Sciences, Ukrainian SSR

Shirshov Institute of Oceanology, Gelendzhik
Academy of Sciences, USSR

Shirshov Institute of Oceanology, Lyublino
Academy of Sciences, USSR

Shirshov Institute of Oceanology, Leningrad
Academy of Sciences, USSR

Institute of Permafrost Studies, Yakutsk
Siberian Department, Academy of Sciences, USSR

Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation, Krasnaya Pakhra
Academy of Sciences, USSR

Institute of Terrestrial Magnetism, Ionosphere, and Radiowave Propagation, Leningrad
Academy of Sciences, USSR

Institute of Geology of Mineral Deposits, Petrography, Mineralogy, and Geochemistry, Moscow
Academy of Sciences, USSR

Little Science

Pacific Ocean Institute of Oceanology, Vladivostok
Far Eastern Scientific Center, Academy of Sciences, USSR

Institute of Seismology, Frunze
Academy of Sciences, Kirgiz SSR

Institute of Seismology, Tashkent
Academy of Sciences, Uzbek SSR

Polar Institute of Geophysics, Murmansk
Kola Affiliate, Academy of Sciences, USSR

Tashkent Central Seismic Station, Tashkent
Academy of Sciences, Uzbek SSR

Institute of Geology and Useful Minerals, Kishinev
Academy of Sciences, Moldavian SSR

Institute of Hydrogeology and Hydrophysics, Alma Ata
Academy of Sciences, Kazakh SSR

Siberian Institute of Terrestrial Magnetism, Ionosphere, and Radio-waves, Irkutsk
East Siberian Affiliate, Academy of Sciences, USSR

LEVEL 3

Big Science

Institute of Geotechnical Mechanics, Dnepropetrovsk
Academy of Sciences, Ukrainian SSR

All-Union Scientific Research Institute of Economics of Mineral Raw Materials and Geological Exploration, Moscow
Academy of Sciences, USSR

Little Science

Institute of Geophysics and Engineering Seismology, Leninakan
Academy of Sciences, Armenian SSR

Institute of Seismological Construction and Seismology, Dushanbe
Academy of Sciences, Tadzhik SSR

Institute of Antiseismic Construction, Ashkhabad
Academy of Sciences, Turkmen SSR

Institute of Construction Mechanics and Seismic Stability, Tbilisi
Academy of Sciences, Georgian SSR

MINERALOGY AND MINING

LEVEL 1

Big Science

Institute of Experimental Mineralogy, Moscow
Academy of Sciences, USSR

Institute of Geochemistry and Mineral Physics, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Chemistry of Oils, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Petroleum Chemistry, Tomsk
Siberian Department, Academy of Sciences, USSR

Little Science

Institute of Chemistry of Petroleum and Natural Salts, Gur'yev
Academy of Sciences, Kazakh SSR

Institute of Physics and Mechanics of Rocks, Frunze
Academy of Sciences, Kirgiz SSR

LEVEL 3

Big Science

Institute of Physical and Chemical Foundations of Mineral Processing, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of Mineral Resources, Simferopol'
Academy of Sciences, Ukrainian SSR

Topchiyev Institute of Petrochemical Synthesis, Moscow
Academy of Sciences, USSR

Institute of Geology and Processing of Mineral Fuels, Moscow
Academy of Sciences, USSR

Little Science

Institute of Chemistry and Technology of Rare Elements and Mineral Raw Materials, Kola
Kola Affiliate, Academy of Sciences, USSR

Institute of Problems of Deep-Petroleum Gas Deposits, Baku
Academy of Sciences, Azerbaydzhan SSR

Mamedaliyev Institute of Petrochemical Processes, Baku
Academy of Sciences, Azerbaydzhan SSR

LEVEL 4

Big Science

Institute of Mining Affairs, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Fedorov Institute of Mining, Donetsk
Academy of Sciences, Ukrainian SSR

Institute of Gas Utilization, Kiev
Academy of Sciences, Ukrainian SSR

Little Science

Institute of Mining Affairs, Alma Ata
Academy of Sciences, Kazakh SSR

Institute of Mining, Murmansk
Kola Affiliate, Academy of Sciences, USSR

Tsulukidze Institute of Mining Mechanics, Development of Deposits, and Physics of Explosions, Tbilisi
Academy of Sciences, Georgian SSR

Scientific Research Institute of Complex Automation of Production Processes in the Petrochemical Industry, Sumgait
Academy of Sciences, Azerbaydzhan SSR

Yakutsk Scientific Research and Planning Institute of the Diamond Industry, Yakutsk
Academy of Sciences, USSR

CIVIL AND MECHANICAL ENGINEERING

LEVEL 3

Big Science

Institute of Engines, Moscow
Academy of Sciences, USSR

Institute of Problems of Machine Building, Khar'kov
Academy of Sciences, Ukrainian SSR

Institute of Strength Problems, Kiev
Academy of Sciences, Ukrainian SSR

Institute of Water Problems, Moscow
Academy of Sciences, USSR

Design Bureau of Hydraulic Impulse Engineering, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Little Science

Institute of Water Problems, Dushanbe
Academy of Sciences, Tadzhik SSR

Azerbaydzhan Scientific Research Institute of Water Problems, Baku
Academy of Sciences, Azerbaydzhan SSR

Institute of Problems of Machine Reliability and Longevity, Minsk
Academy of Sciences, Belorussian SSR

Institute of Water Problems and Hydrotechnics, Tashkent
Academy of Sciences, Uzbek SSR

AEROSPACE

LEVEL 2

Big Science

Institute of Space Research, Moscow
Academy of Sciences, USSR

INFORMATION SCIENCE AND MANAGEMENT

LEVEL 2

Big Science

All-Union Institute of Scientific and Technical Information, Moscow
Academy of Sciences, USSR

Institute of Problems of Information Transmission, Moscow
Academy of Sciences, USSR

LEVEL 4

Big Science

All-Union Institute of Planning Scientific Research Institutes and Laboratories, Moscow
Academy of Sciences, USSR

Institute of the Economics and Organization of Industrial Production, Novosibirsk
Siberian Department, Academy of Sciences, USSR

Institute of the Economics of Industry, Donetsk
Academy of Sciences, Ukrainian SSR

Appendix B

DISTRIBUTION OF SCIENTIFIC WORKERS

Table B.1

DISTRIBUTION OF SCIENTIFIC WORKERS BY REPUBLIC AND SECTOR, 1975[a]

Republic	VUZ Budget[b] (Millions of Rubles)	Scientific Workers			
		Academy of Sciences[c]	VUZ[d]	Industry and Other[e]	Total[f]
RSFSR	1245.2	41,836	236,612	560,052	838,500
Ukraine	412.8	12,102	78,440	80,958	171,500
Belorussia	84.2	4,640	16,000	10,360	31,000
Uzbekistan	102.0	3,699	19,382	7,819	30,900
Kazakhstan	101.0	3,731	19,344	8,925	32,000
Georgia	45.4	5,493	8,627	10,880	25,000
Azerbaydzhan	53.2	4,222	10,109	6,969	21,300
Lithuania	35.1	1,534	6,670	4,296	12,500
Moldavia	25.6	883	4,864	1,553	7,300
Latvia	22.6	1,760	4,294	5,946	12,000
Kirgizia	26.6	1,434	5,054	612	7,100
Tadzhikistan	26.8	1,213	5,092	295	6,600
Armenia	41.0	2,835	7,791	6,474	17,100
Turkmenia	15.0	866	2,850	884	4,600
Estonia	16.1	949	3,059	1,992	6,000
Total	2253.4	87,197	428,190	708,015	1,223,400

[a]Data represent all fields, including those not relevant to technological development.

[b]*Gosudarstvennyy byudzhet SSSR i byudzhety soyuznykh respublik* (State Budget of the USSR and Budgets of Union Republics), *Statistika* Publishing House, Moscow, 1971, 1976.

[c]*Narodnoye khozyaystvo SSSR v 1975 g.* (National Economy of the USSR, 1975), *Statistika* Publishing House, Moscow, 1976, p. 167.

[d]On the assumption that the number of VUZ scientific workers in a republic is proportional to the VUZ budget for that republic, a multiplier was derived as follows: The total number of VUZ scientific workers in the USSR in the mid-1970s was 35 percent of all scientific workers, or 428,190 (C. P. Ailes, J. E. Cole, and H. T. Ellis, "Summary of Soviet Report on the Training and Utilization of Scientific, Engineering, and Technical Personnel in the USSR" [Draft], Stanford Research Institute, Arlington, Va., 1977, p. 91). The multiplier is the quotient of this number divided by the total VUZ budgets for all republics.

[e]Total number of scientific workers minus total Academy of Science and VUZ workers.

[f]*Narodnoye khozyaystvo SSSR v 1975 g.*, p. 166.

Table B.2

PERCENT DISTRIBUTION OF SCIENTIFIC WORKERS BY REPUBLIC AND SECTOR, 1975[a]

	Academy of Sciences	VUZ	All Others
USSR	7	35	58
RSFSR	5	28	67
Ukraine	7	46	47
Belorussia	15	52	33
Uzbekistan	12	63	25
Kazakhstan	12	60	28
Georgia	22	35	43
Azerbaydzhan	20	47	33
Lithuania	12	54	34
Moldavia	12	67	21
Latvia	15	36	49
Kirgizia	20	71	9
Tadzhikistan	18	77	5
Armenia	17	46	37
Turkmenia	19	62	19
Estonia	16	51	33

[a]From Table B.1.